Hydraulic Transient Calculation Report

[UPPER TRISHULI-1 HEP (216MW)]

2023. 03. 09.

DOOSAN Enerbility

FOR APPROVAL

0E	9.MAR.2023	Sameer Sahai	J. M. KIM	Y.S.SON	For Approval
0D	28.JUL.2022	Sameer Sahai	J. M. KIM	Y.S.SON	For Approval
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0B	14.APR.2022	Sameer Sahai	J. M. KIM	Y.S.SON	For Approval
0A	26.JAN.2022	Sameer Sahai	J. M. KIM	Y.S.SON	For Approval
REV	**DATE**	**PREPARED**	**CHECKED**	**APPROVED**	**STATUS**

Project

Upper Trishuli-1 HEP (216MW)

Owner

NWEDC NEPAL WATER AND ENERGY DEVELOPMENT CO. PVT.LTD.

Owner's Engineer

TRACTEBEL ENGIE

jade CONSULT

Contractor

DOOSAN Enerbility

Document Title

Hydraulic Transient Calculation Report

Discipline: Turbine

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0A	26.JAN.2022		First Issue
0B	14.APR.2022		As per RN-0059
0C	15.JUL.2022		As per RN-0118
0D	28.JUL.2022		As per RN-0192
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CONTENTS

1 INTRODUCTION 4
2 CALCULATION METHOD 4
3 INPUT DATA 5
3.1 Waterways 5
3.2 Surge Tank 22
3.2.1 Surge Tank at Upstream 22
3.2.2 Surge Gallery at Downstream 22
3.2.3 Desander Basins 22
3.3 Motor-Generator 22
3.4 Main Inlet Valves 23
3.4.1 Opening and closing law of MIV 23
3.5 Distributor 23
4 MANEUVER EXPLANATIONS 24
4.1 Load Rejection / Quick Shut Down triggered by electric reason (QSD-E) 24
4.2 Emergency Shut Down (ESD) 24
4.3 Loading of the turbine (LA) 24
4.4 Runaway (Runaway) 24
4.5 Loading of the turbine (LA) followed by Load Rejection / Quick Shut Down (QSD-E) 24
4.6 Load Rejection / Quick Shut Down (QSD-E) + Speed No Load (SNL) + Loading of the turbine (LA) 24
5 CALCULATION RESUTLS 25
6 CONCLUSIONS 27
7 REFERENCES 27
8 ENCLOSURES 28
ANNEXURE-1: Hydraulic Gradient Lines for Water Conductor System 79
ANNEXURE-2: Verification using the Thoma Stability Criterion for Mass Oscillations in Surge Tanks 92
ANNEXURE-3: Justification of Requirement of Draft Tube Shaft as Surge Tank 93
ANNEXURE-4: Impact of Connection Pipe (Orifice) Size on U.S.W.L and Pressure in HRT 95

1 INTRODUCTION

Hydraulic Transient calculations have been done in the order stage of the Upper Trishuli-1 HEP to investigate the transient behavior of the plant. Analyzed are the relevant most critical cases to determine the related guarantees which are stated in the contract documents. The report hereafter deals with the Three Francis turbines. The calculation is done using the actual turbine characteristic received from the homologues model of the Upper Trishuli-1 HEP.

The most important data of Upper Trishuli-1 HEP are listed below:

Turbines:		Vertical Francis turbines	
Runner diameter	D2	1.581 m	
Rated speed	N	428.57 rpm	
Runner Centerline	CL	906.0 masl	
Max. static head	Hstmax	349.0 m (1255-906)	
Turbine max. power	Pmax	74.5 MW	
Design Discharge	Q	24.72 m3/s	Rev.0D
Moment of Inertia	WR^2	187.5 tm^2	

Transient constraints for this investigation are:

- Permissible penstock pressure is ≤ 425.0 mwc
- Permissible rotational speed is ≤ 621.43 rpm (145% of rated speed)
- Permissible runaway speed is ≤ 690.00 rpm

The report hereafter deals with the Three Francis turbines – Upper Trishuli-1 HEP.

2 CALCULATION METHOD

The program package SIMSEN (Ref.1) / WHIPSIM has been used for the present study. A variable time step has been used.

The results are presented as diagrams versus time. The initial, maximum, and minimum values of the output variables are automatically extracted from the output files. They are presented as tables within the diagrams.

3 INPUT DATA

In the following sub-chapters, the main input data and simulation model for the transient analysis are presented.

3.1 Waterways

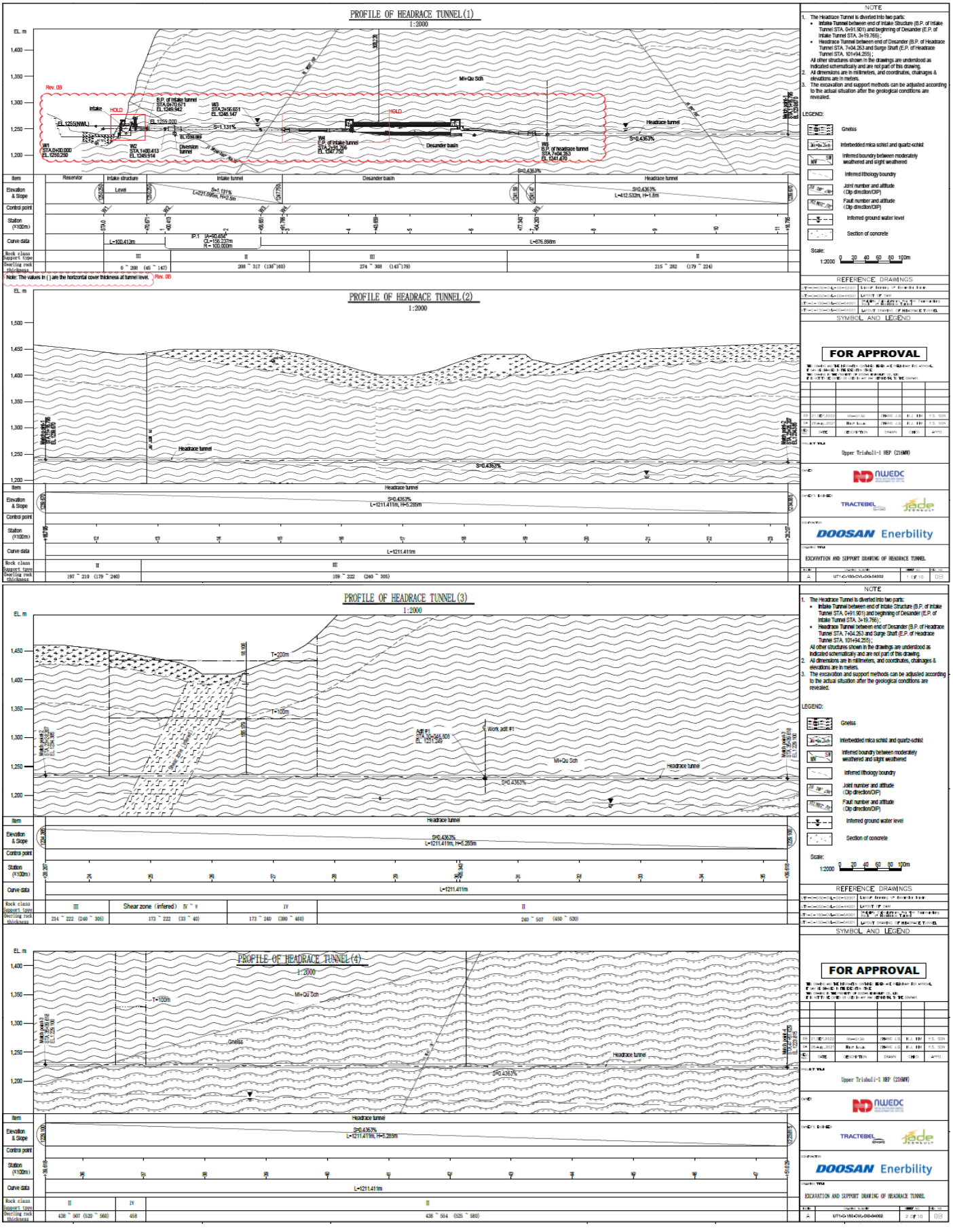
The waterway system is modeled accordingly to the data and drawings given in the specification.

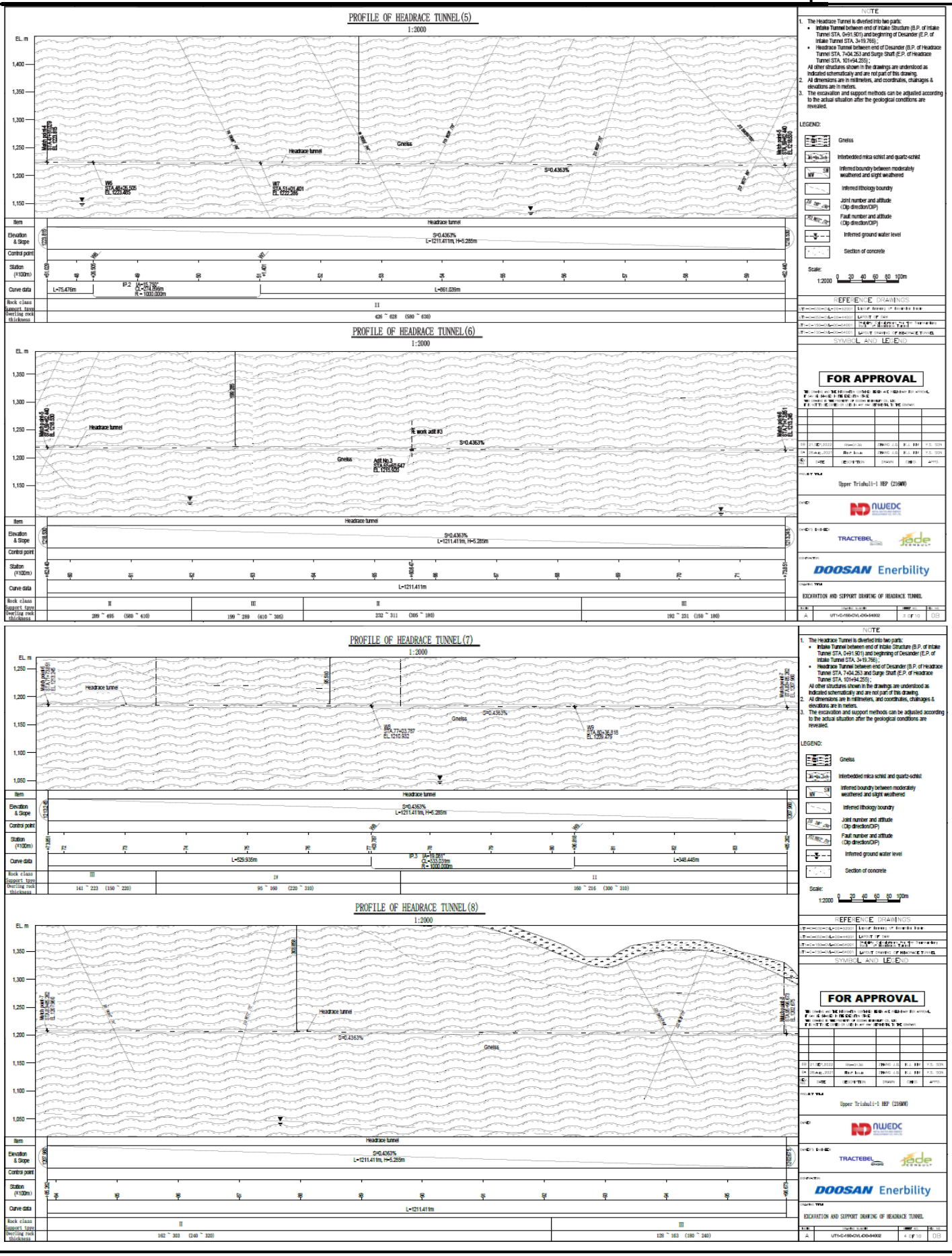
Weir Water Level		
Operating water level	1255.0	m
Normal high water level, FRL	1255.0	m
Tail Race Water Level		
Water level at three units full load operation	914.11	m
Water level at one unit full load operation	912.41	m
Minimum water level (no discharge)	910.00	m
Maximum Head Loss (at discharge of 76.0m3/s)	**13.91**	**m**
Centre line of turbine (spiral case)	**906.00**	**m**
Operating Net Heads		
Rated net head	327.00	m
Maximum net head	341.70	m
Minimum net head	327.00	m

Following drawings and data are used as input to this calculation:

Rev.0E

Title:	Date:	Drawing/Document No.:
Excavation And Support Drawing of Headrace Tunnel	21SEPT2022	UT1-C-150-CVL-DG-54002_0B
Layout drawing of desander basin	25DEC 2022	UT1-C-030-CVL-DG-52001_0C
Layout Drawing of Tailrace System	20APR2022	UT1-C-070-CVL-DG-59001_0D
Layout Drawing of Steel Penstock Tunnel	30DEC2021	UT1-C-060-CVL-DG-58005_0C
Attachment-1 Head Loss Calculation of Waterway for UT1 (Scheme 3- by Laxman)	-	-
Layout Drawing of Surge Tank	02OCT2022	UT1-C-040-CVL-DG-57001_0A
Layout Drawing of Pressure Tunnel	07NOV2022	UT1-C-060-CVL-DG-58001_0A


PROFILE OF HEADRACE TUNNEL(1)
1:2000
PROFILE OF HEADRACE TUNNEL(2)
1:2000
PROFILE OF HEADRACE TUNNEL(3)
1:2000
PROFILE OF HEADRACE TUNNEL(4)
1:2000
NOTE
1. The Headrace Tunnel is diverted into two parts:
Intake Tunnel between end of Intake Structure (B.P. of Intake Tunnel STA. 0+91.901) and beginning of Desander (E.P. of Intake Tunnel STA. 3+19.766) ;
Headrace Tunnel between end of Desander (B.P. of Headrace Tunnel STA. 7+04.263 and Surge Shaft (E.P. of Headrace Tunnel STA. 10+94.255) ;
All other structures shown in the drawings are understood as indicated schematically and are not part of this drawing.
2. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
3. The excavation and support methods can be adjusted according to the actual situation after the geological conditions are revealed.
LEGEND:
Gneiss
Interbedded mica schist and quartz-schist
Inferred boundry between moderately weathered and slight weathered
Inferred lithology boundry
Joint number and attitude (Dip direction/DIP)
Fault number and attitude (Dip direction/DIP)
Inferred ground water level
Section of concrete
Scale:
1:2000
REFERENCE DRAWINGS
SYMBOL AND LEGEND
FOR APPROVAL
Upper Trishuli-1 HEP (216MW)
NWEDC
TRACTEBEL ENGIE
jade
DOOSAN Enerbility
EXCAVATION AND SUPPORT DRAWING OF HEADRACE TUNNEL
UT1-G-150-CVL-DG-04002
1 OF 10
03


PROFILE OF HEADRACE TUNNEL(5)
1:2000
PROFILE OF HEADRACE TUNNEL(6)
1:2000
PROFILE OF HEADRACE TUNNEL(7)
1:2000
PROFILE OF HEADRACE TUNNEL(8)
1:2000
Headrace tunnel
Gneiss
S=0.4363%
L=1211.411m, H=5.285m
NOTE
1. The Headrace Tunnel is diverted into two parts:
Intake Tunnel between end of Intake Structure (B.P. of Intake Tunnel STA. 0+91.901) and beginning of Desander (E.P. of Intake Tunnel STA. 3+19.766) ;
Headrace Tunnel between end of Desander (B.P. of Headrace Tunnel STA. 7+04.263 and Surge Shaft (E.P. of Headrace Tunnel STA. 101+94.255) ;
All other structures shown in the drawings are understood as indicated schematically and are not part of this drawing.
2. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
3. The excavation and support methods can be adjusted according to the actual situation after the geological conditions are revealed.
LEGEND:
Gneiss
Interbedded mica schist and quartz-schist
Inferred boundry between moderately weathered and slight weathered
Inferred lithology boundry
Joint number and attitude (Dip direction/DIP)
Fault number and attitude (Dip direction/DIP)
Inferred ground water level
Section of concrete
Scale:
1:2000
REFERENCE DRAWINGS
SYMBOL AND LEGEND
FOR APPROVAL
Upper Trishuli-1 HEP (216MW)
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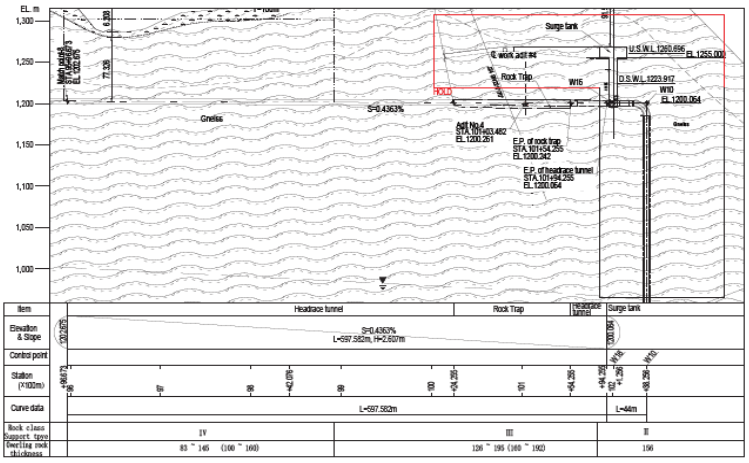
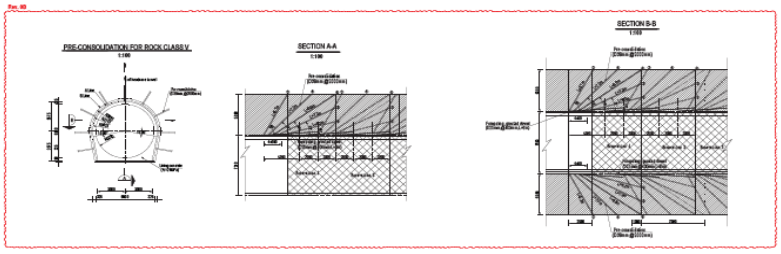
EXCAVATION AND SUPPORT DRAWING OF HEADRACE TUNNEL

PROFILE OF HEADRACE TUNNEL (9)
1:2000





NOTE
1. The Headrace Tunnel is diverted into two parts:
   - Intake Tunnel between end of Intake Structure (B.P. of Intake Tunnel STA. 0+91.501) and beginning of Desander (E.P. of Intake Tunnel STA. 3+19.766) ;
   - Headrace Tunnel between end of Desander (B.P. of Headrace Tunnel STA. 7+04.263 and Surge Shaft (E.P. of Headrace Tunnel STA. 101+64.255) ;

   All other structures shown in the drawings are understood as indicated schematically and are not part of this drawing.
2. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
3. The excavation and support methods can be adjusted according to the actual situation after the geological conditions are revealed.

LEGEND:

Gneiss
Interbedded mica schist and quartz-schist
Inferred boundry between moderately weathered and slight weathered
Inferred lithology boundry
Joint number and attitude (Dip direction/DIP)
Fault number and attitude (Dip direction/DIP)
Inferred ground water level
Section of concrete

Scale: 1:2000 0 20 40 60 80 100m

REFERENCE DRAWINGS
SYMBOL AND LEGEND

FOR APPROVAL

Upper Trishuli-1 HEP (216MW)

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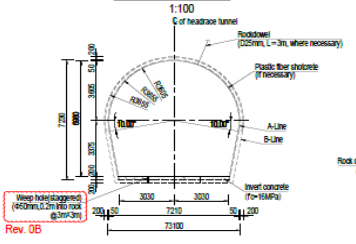
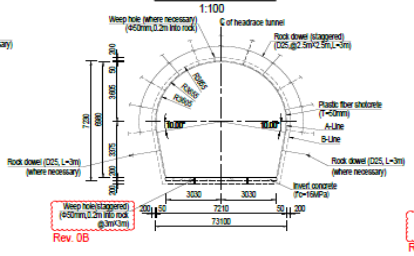
EXCAVATION AND SUPPORT DRAWING OF HEADRACE TUNNEL

A | UT1-C-100-DVL-DG-54002 | 9 OF 10 | 0B

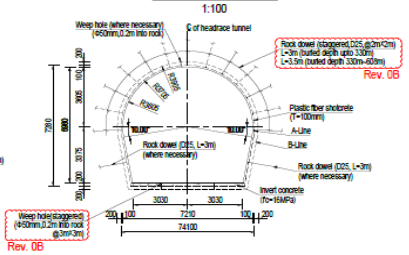
SUPPORT TYPE I
1:100



SUPPORT TYPE II
1:100



SUPPORT TYPE III
1:100


Weep hole (where necessary) (ø50mm,0.2m into rock)
℄ of headrace tunnel
Rock dowel (staggered,D25,@2m*2m) L=3m (buried depth upto 330m) L=3.5m (buried depth 330m~600m)
Rev. 0B
Plastic fiber shotcrete (T=100mm)
A-Line
B-Line
Rock dowel (D25, L=3m) (where necessary)
Invert concrete (fc'=16MPa)
Weep hole(staggered) (ø50mm,0.2m into rock @3m*3m)
Rev. 0B

NOTE
1. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
2. The steel support (or lattice girder) to rock class IV is subjected to the exposed geological condition.
3. The foregoing for class V is subjected to the exposed geological condition and constructability.
4. The cylinder specified compressive strength of shotcrete and cement mortar at 28 days of age is 25MPa.
5. The specified compressive strength of concrete is the cylinder strength at age of 28 days.
6. The thickness of concrete cover of steel reinforcement is 50mm.
7. Symbol description:
   A-Line is the design excavation line.
   B-Line is the overbreak line.
   R denotes round bar, yield strength of the round bar is 280MPa.
   D denotes deformed bar, yield strength of the deformed bar is 500MPa.
8. The detail of weep holes, rock dowel, steel support and steel lattice girder see the drawing No. UT1-C-000-CVL-DG-40001.

LEGEND:

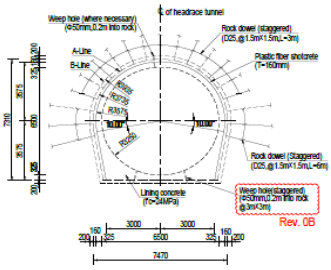
Section of concrete, fc'=16MPa
Section of concrete_ fc'=24MPa
Excavation line

Scale: 1:50 0 0.5 1.0 1.5 2.0 2.5m
1:100 0 1 2 3 4 5m

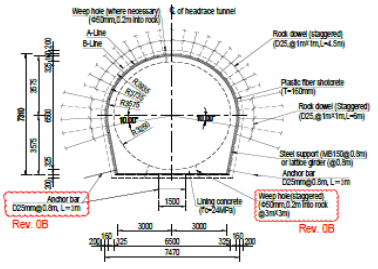
REFERENCE DRAWINGS
SYMBOL AND LEGEND

FOR APPROVAL

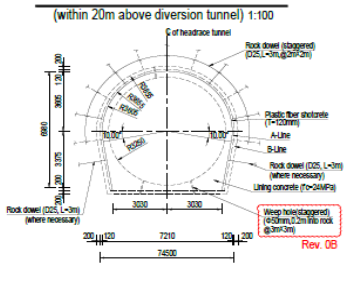
SUPPORT TYPE IV (Burial depth upto 240m)
(Without steel support) 1:100



SUPPORT TYPE IV (Burial depth 240m to 458m)
(With steel support) 1:100



SUPPORT TYPE S
(within 20m above diversion tunnel) 1:100



Upper Trishuli-1 HEP (216MW)

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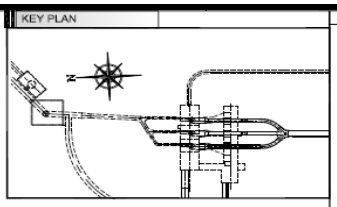
EXCAVATION AND SUPPORT DRAWING OF HEADRACE TUNNEL (6/10)

A | UT1-C-100-DVL-DG-54002-06 | 6 OF 10 | 0B

Coordinate of control points

No.	X(E) (m)	Y(E) (m)	Remark
W0	3107206.255	619126.258	
PV1	3107225.587	619149.199	
PV2	3107166.647	619122.334	

KEY PLAN

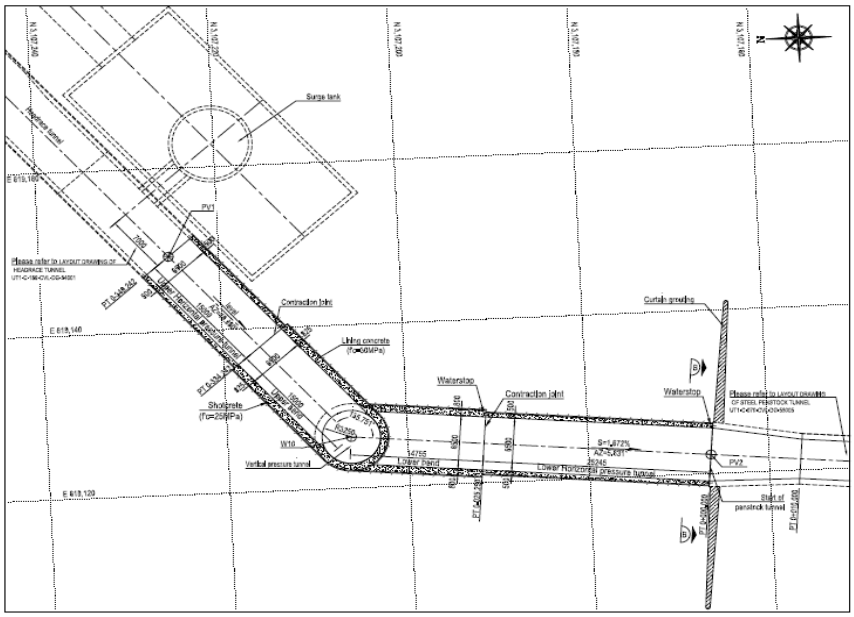


NOTE

1. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
2. Symbol description:
   2.1. A-A is the design excavation line.
   2.2. B-B is the overbreak line.
   2.3. D denotes deformed bar, yield strength of the deformed bar is 500Mpa.
3. The specified compressive strength of lining concrete and backfill concrete is respectively the cylinder strength of 30MPa and 21MPa at age of 28 days.
4. The cylinder strength of shotcrete at 28 days of age is 25MPa.
5. Backfill grouting is applied to tunnel crown, consolidation grouting is applied to rock class IV and V.
6. The spacing of construction joints is set according to the construction measures.

PLAN LAYOUT OF PRESSURE TUNNEL

Scale 1:200



Legend

Excavation line

Section of concrete

Scale:

1:200 0 2 4 6 8 10m

REFERENCE DRAWINGS

UT1-D-048-CIG-2004-0001	LAYOUT OF SURGE TANK
UT1-D-184-CIG-2004-0001	LAYOUT DRAWING OF HEADRACE TUNNEL
UT1-D-413-D(4)-CIG-4000	LAYOUT DRAWING OF STEEL PENSTOCK TUNNEL

SYMBOL AND LEGEND

FOR APPROVAL

NO.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
0A	07.NOV.2022	FIRST ISSUE	GUO YAO	K.J. KIM	Y.S. SON

PROJECT TITLE: Upper Trishuli-1 HEP (216MW)

OWNER: NWEDC

OWNER'S ENGINEER: TRACTEBEL ENGINEERING, jade CONSULT

CONTRACTOR: DOOSAN Enerbility

DRAWING TITLE: Layout drawing of pressure tunnel

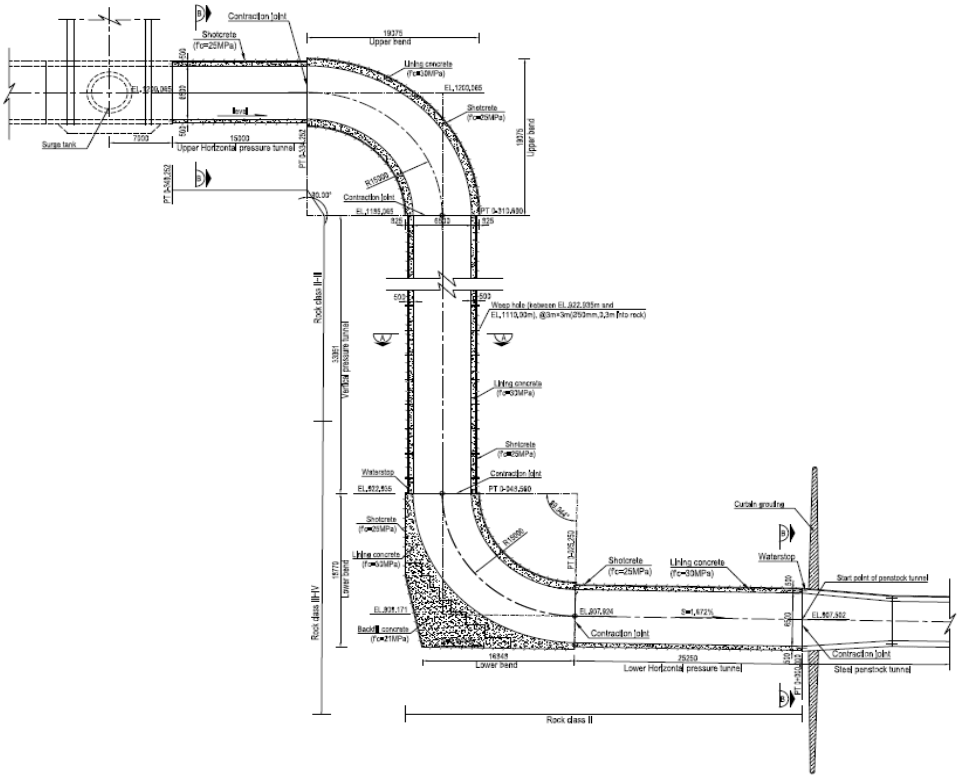
SCALE	DRAWING NUMBER	SHEET NO.	REV. NO.
A	UT1-C-355-CVL-CIG-58301	1 OF 4	0A

NOTE

1. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
2. Other notes, refer to sheet 1.

PROFILE OF PRESSURE TUNNEL

Scale 1:200



Scale:

1:100 0 0.5 1 1.5 2 2.5m

1:200 0 2 4 6 8 10m

REFERENCE DRAWINGS

UT1-D-048-CIG-2004-0001	LAYOUT OF SURGE TANK
UT1-D-184-CIG-2004-0001	LAYOUT DRAWING OF HEADRACE TUNNEL
UT1-D-413-D(4)-CIG-4000	LAYOUT DRAWING OF STEEL PENSTOCK TUNNEL

SYMBOL AND LEGEND

FOR APPROVAL

NO.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
0A	07.NOV.2022	FIRST ISSUE	GUO YAO	K.J. KIM	Y.S. SON

PROJECT TITLE: Upper Trishuli-1 HEP (216MW)

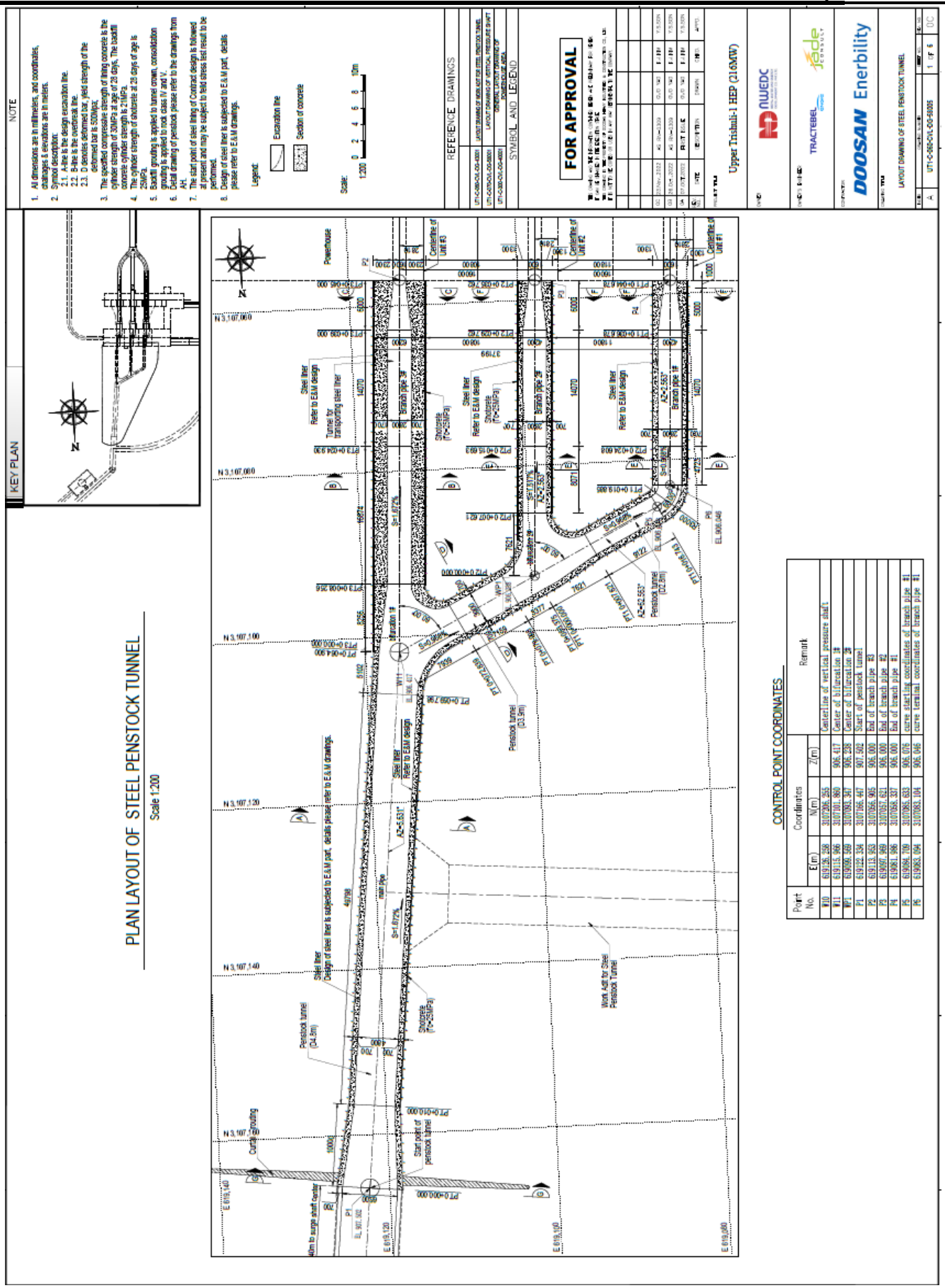
OWNER: NWEDC

OWNER'S ENGINEER: TRACTEBEL ENGINEERING, jade CONSULT

CONTRACTOR: DOOSAN Enerbility

DRAWING TITLE: Layout drawing of pressure tunnel

SCALE	DRAWING NUMBER	SHEET NO.	REV. NO.
A	UT1-C-355-CVL-CIG-58301	2 OF 4	0A


NOTE
1. All dimensions are in millimeters, and coordinates, chainages & eexcations are in meters.
2. Symbol description:
2.1. A-line is the design excavation line.
2.2. B-line is the overbreak line.
2.3. D denotes deformed bar, yield strength of the deformed bar is 500Mpa.
3. The specified compressive strength of lining concrete is the cylinder strength of 30MPa at age of 28 days. The backfill concrete cylinder strength is 21MPa.
4. The cylinder strength of shotcrete at 28 days of age is 25MPa.
5. Backfill grouting is applied to tunnel crown, consolidation grouting is applied to rock class IV and V.
6. Detail drawing of penstock please refer to the drawings from A1.
7. The start point of steel lining of Contract design is followed at present and may be subject to field stress test result to be performed.
8. Design of steel liner is subjected to E&M part, details please refer to E&M drawings.
Legend:
Excavation line
Section of concrete
Scale:
1:200
0 2 4 6 8 10m
REFERENCE DRAWINGS
SYMBOL AND LEGEND
FOR APPROVAL
Upper Trishuli-1 HEP (216MW)
NWEDC
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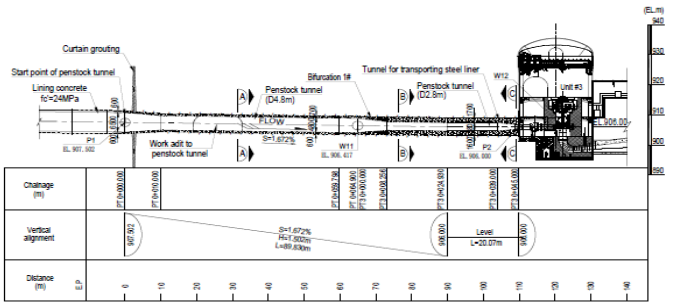
LAYOUT DRAWING OF STEEL PENSTOCK TUNNEL
KEY PLAN
PLAN LAYOUT OF STEEL PENSTOCK TUNNEL
Scale 1:200
CONTROL POINT COORDINATES
Point No.
Coordinates
E(m)
N(m)
Z(m)
Remark
W10 619126.258 3107206.255 906.000 Centerline of vertical pressure shaft
W11 619115.966 3107101.869 906.417 Center of bifurcation 1#
WP1 619098.569 3107083.347 906.258 Center of bifurcation 2#
P1 619102.334 3107166.447 907.502 Start of penstock tunnel
P2 619118.853 3107085.965 906.000 End of branch pipe #3
P3 619097.969 3107057.621 906.000 End of branch pipe #2
P4 619081.986 3107058.337 906.000 End of branch pipe #1
P5 619084.709 3107085.633 906.076 curve starting coordinates of branch pipe #1
P6 619063.094 3107083.104 906.046 curve terminal coordinates of branch pipe #1

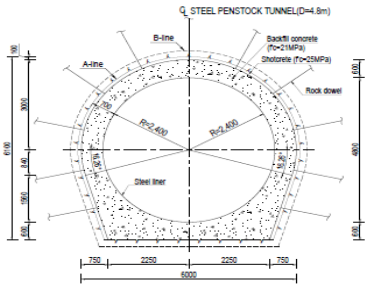
PROFILE OF STEEL PENSTOCK TUNNEL (branch pipe #3)

Scale 1:500



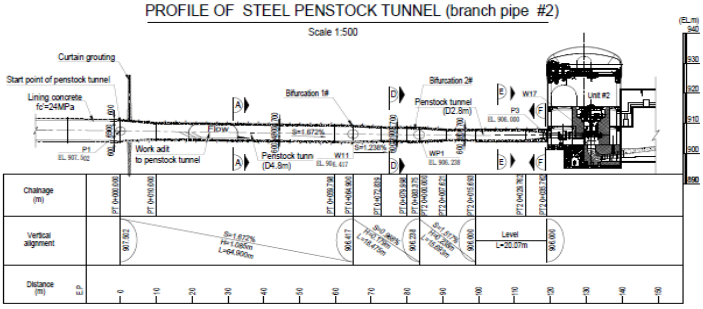
SECTION OF PENSTOCK TUNNEL (SECTION A-A, D=4.8m)

SCALE 1:50



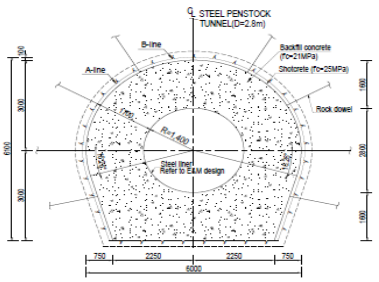
PROFILE OF STEEL PENSTOCK TUNNEL (branch pipe #2)

Scale 1:500



SECTION OF PENSTOCK TUNNEL (SECTION B-B, D=2.8m)

SCALE 1:50



NOTE

1. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
2. Other notes, refer to sheet 1.

Scale:
1:50 0 0.5 1 1.5 2 2.5m
1:500 0 5 10 15 20 25m

REFERENCE DRAWINGS

UT1-C-060-CVL-DG-68001	LAYOUT DRAWING OF WORK ADIT FOR STEEL PENSTOCK TUNNEL
UT1-C-070-CVL-DG-68001	LAYOUT DRAWING OF VERTICAL PRESSURE SHAFT
UT1-C-080-CVL-DG-68001	GENERAL LAYOUT DRAWING OF POWERHOUSE AREA

SYMBOL AND LEGEND

FOR APPROVAL

03	28-Nov-2022	AC	YH	[illegible]	[illegible]
02	04-Oct-2022	AC	YH	[illegible]	[illegible]
01	31-Aug-2022	AC	YH	[illegible]	[illegible]
A	17-Jun-2022	AC	YH	[illegible]	[illegible]
No.	NOTE	DESIGN	CHECK	APP.	DATE

Upper Trishuli-1 HEP (216MW)

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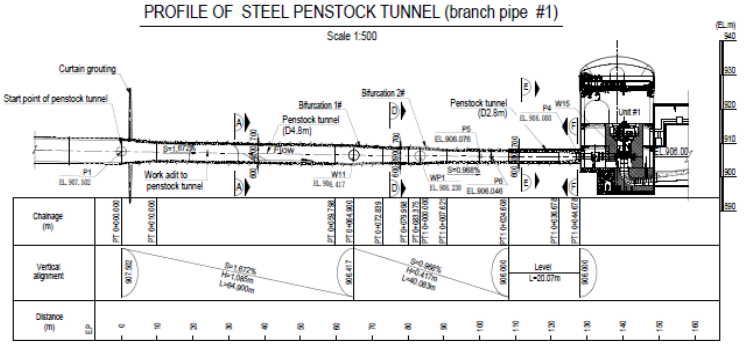
LAYOUT DRAWING OF STEEL PENSTOCK TUNNEL

A	UT1-C-060-CVL-DG-68005	2 OF 6	DC

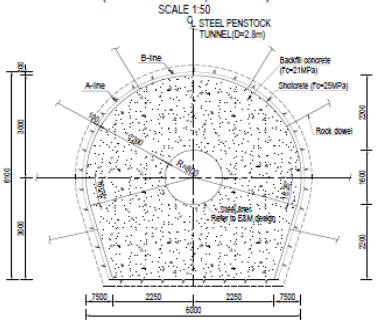
PROFILE OF STEEL PENSTOCK TUNNEL (branch pipe #1)

Scale 1:500



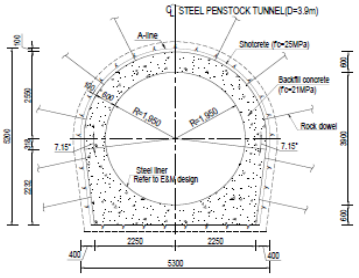
SECTION OF PENSTOCK TUNNEL (SECTION C-C, D=1.6m)

SCALE 1:50



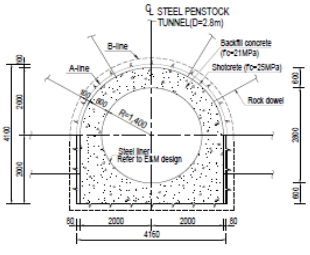
SECTION OF PENSTOCK TUNNEL (SECTION D-D, D=3.9m)

SCALE 1:50



SECTION OF PENSTOCK TUNNEL (SECTION E-E, D=2.8m)

SCALE 1:50



NOTE

1. All dimensions are in millimeters, and coordinates, chainages & elevations are in meters.
2. Other notes, refer to sheet 1.

Scale:
1:50 0 0.5 1 1.5 2 2.5m
1:500 0 5 10 15 20 25m

REFERENCE DRAWINGS

UT1-C-060-CVL-DG-68001	LAYOUT DRAWING OF WORK ADIT FOR STEEL PENSTOCK TUNNEL
UT1-C-070-CVL-DG-68001	LAYOUT DRAWING OF VERTICAL PRESSURE SHAFT
UT1-C-080-CVL-DG-68001	GENERAL LAYOUT DRAWING OF POWERHOUSE AREA

SYMBOL AND LEGEND

FOR APPROVAL

03	28-Nov-2022	AC	YH	[illegible]	[illegible]
02	04-Oct-2022	AC	YH	[illegible]	[illegible]
01	31-Aug-2022	AC	YH	[illegible]	[illegible]
A	17-Jun-2022	AC	YH	[illegible]	[illegible]
No.	NOTE	DESIGN	CHECK	APP.	DATE

Upper Trishuli-1 HEP (216MW)

NWEDC

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LAYOUT DRAWING OF STEEL PENSTOCK TUNNEL

A	UT1-C-060-CVL-DG-68005	3 OF 6	DC

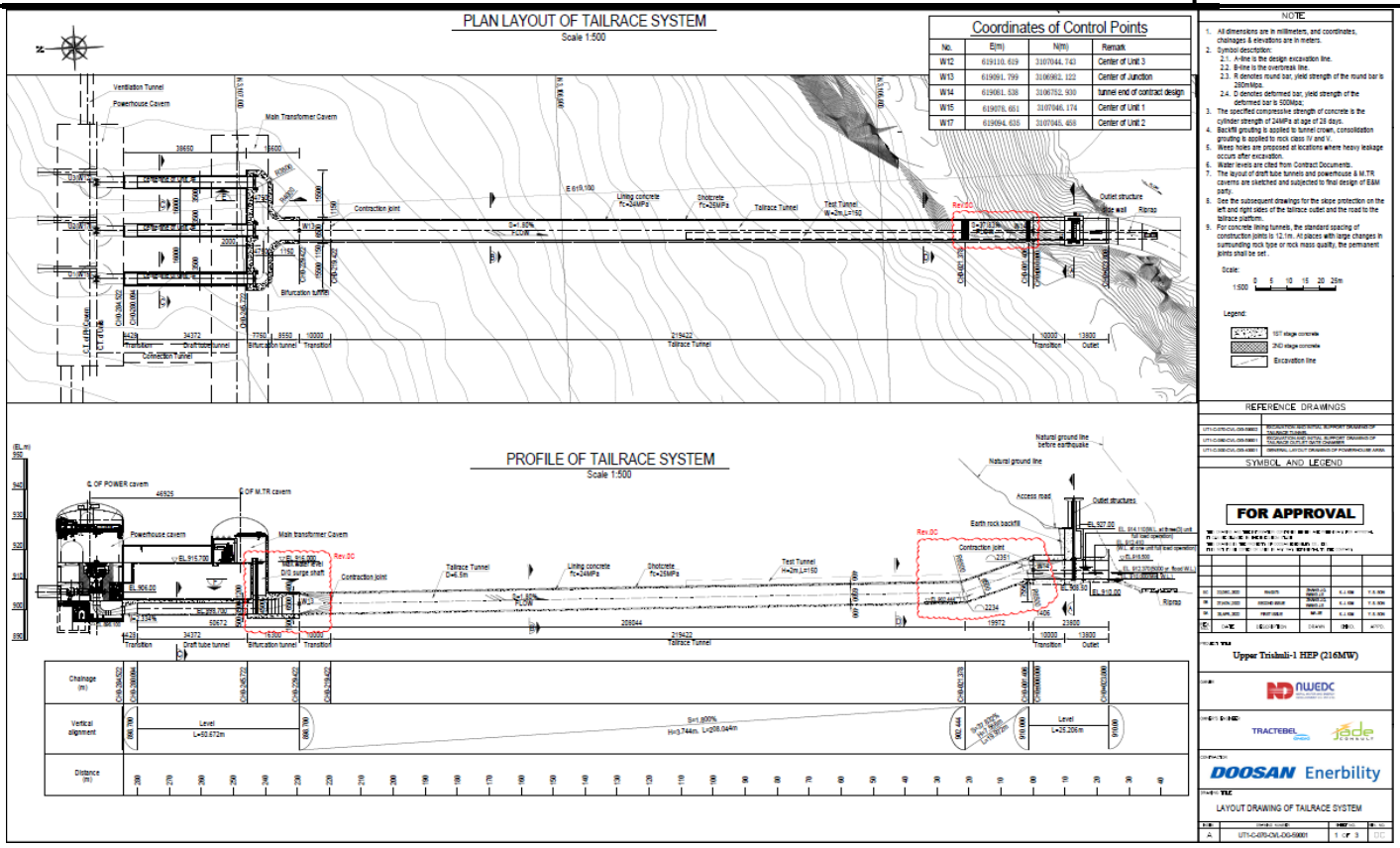
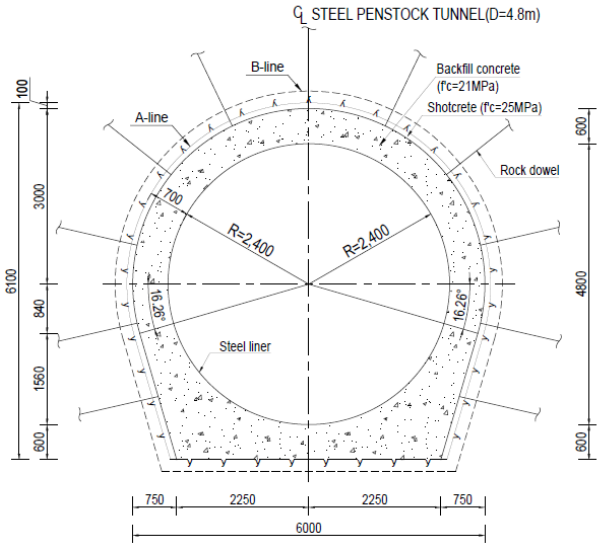


Figure 3.1: Water conductor system

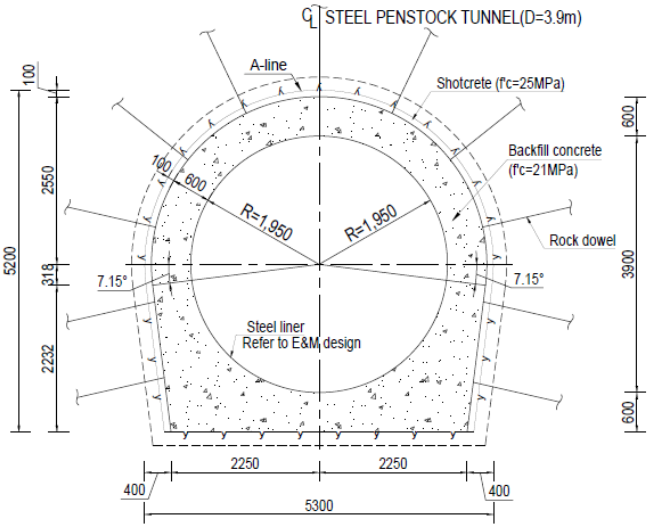
Rev.0E

Rev.0E

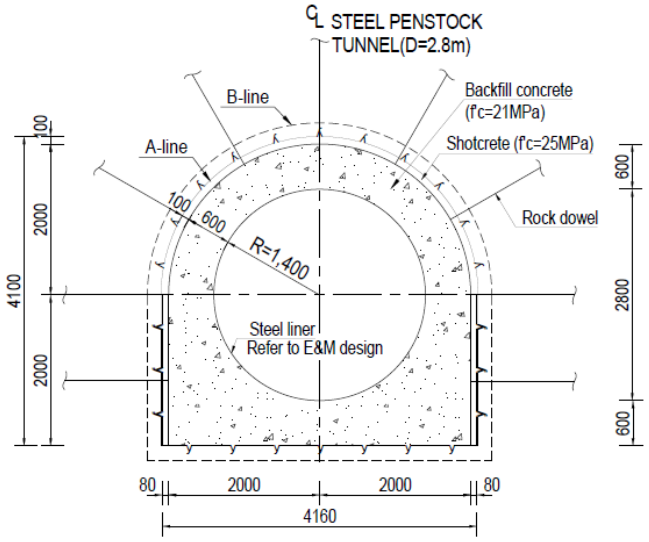
SECTION OF PENSTOCK TUNNEL
(SECTION A-A, D=4.8m)
SCALE 1:50



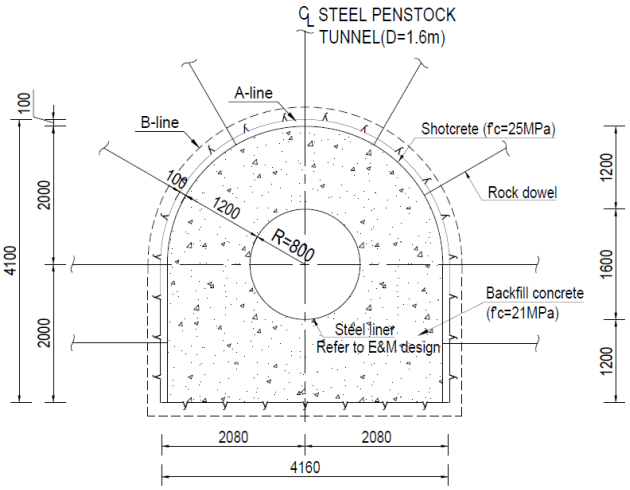
SECTION OF PENSTOCK TUNNEL
(SECTION D-D, D=3.9m)
SCALE 1:50



SECTION OF PENSTOCK TUNNEL
(SECTION E-E, D=2.8m)
SCALE 1:50



SECTION OF PENSTOCK TUNNEL
(SECTION F-F, D=1.6m)
SCALE 1:50



Rev.0E

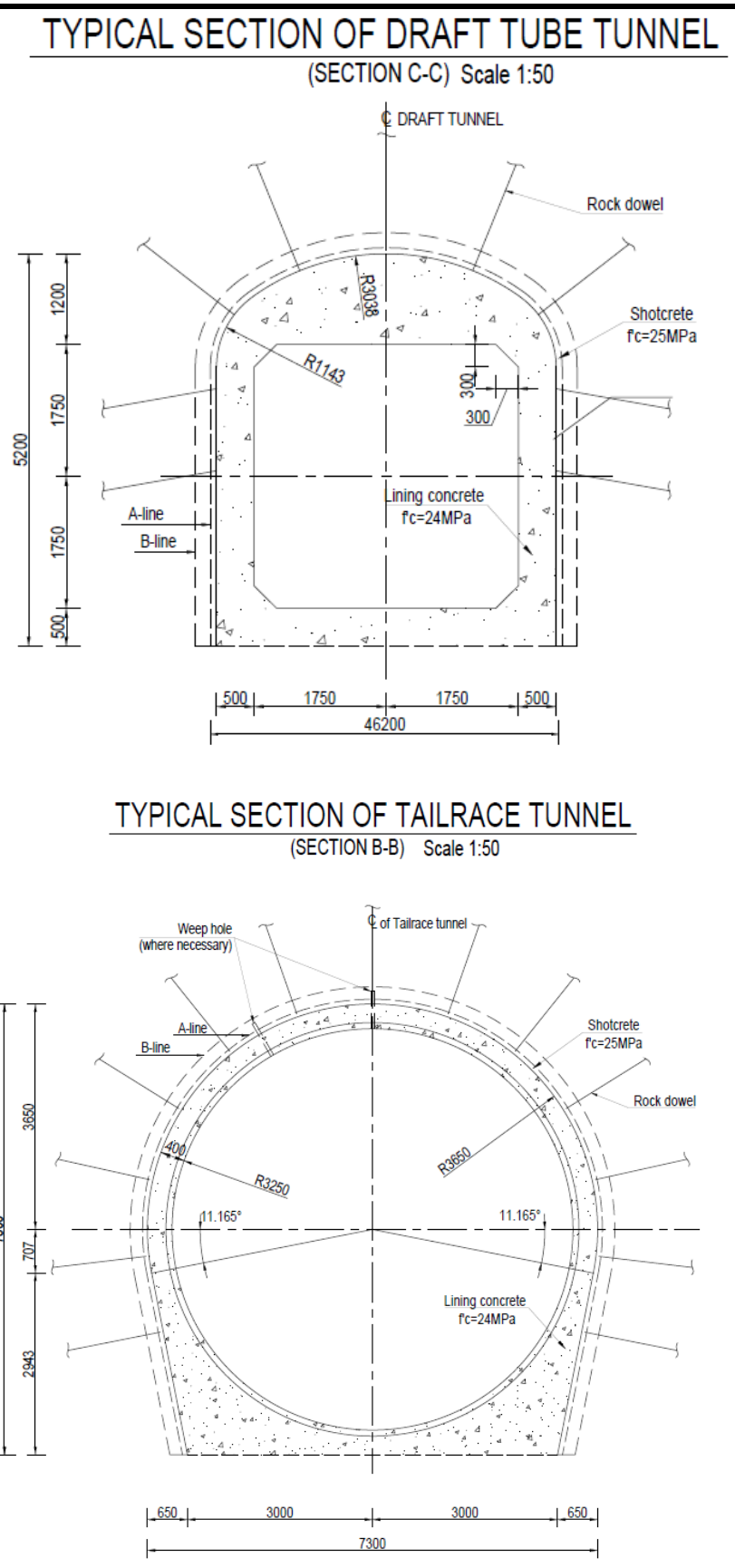
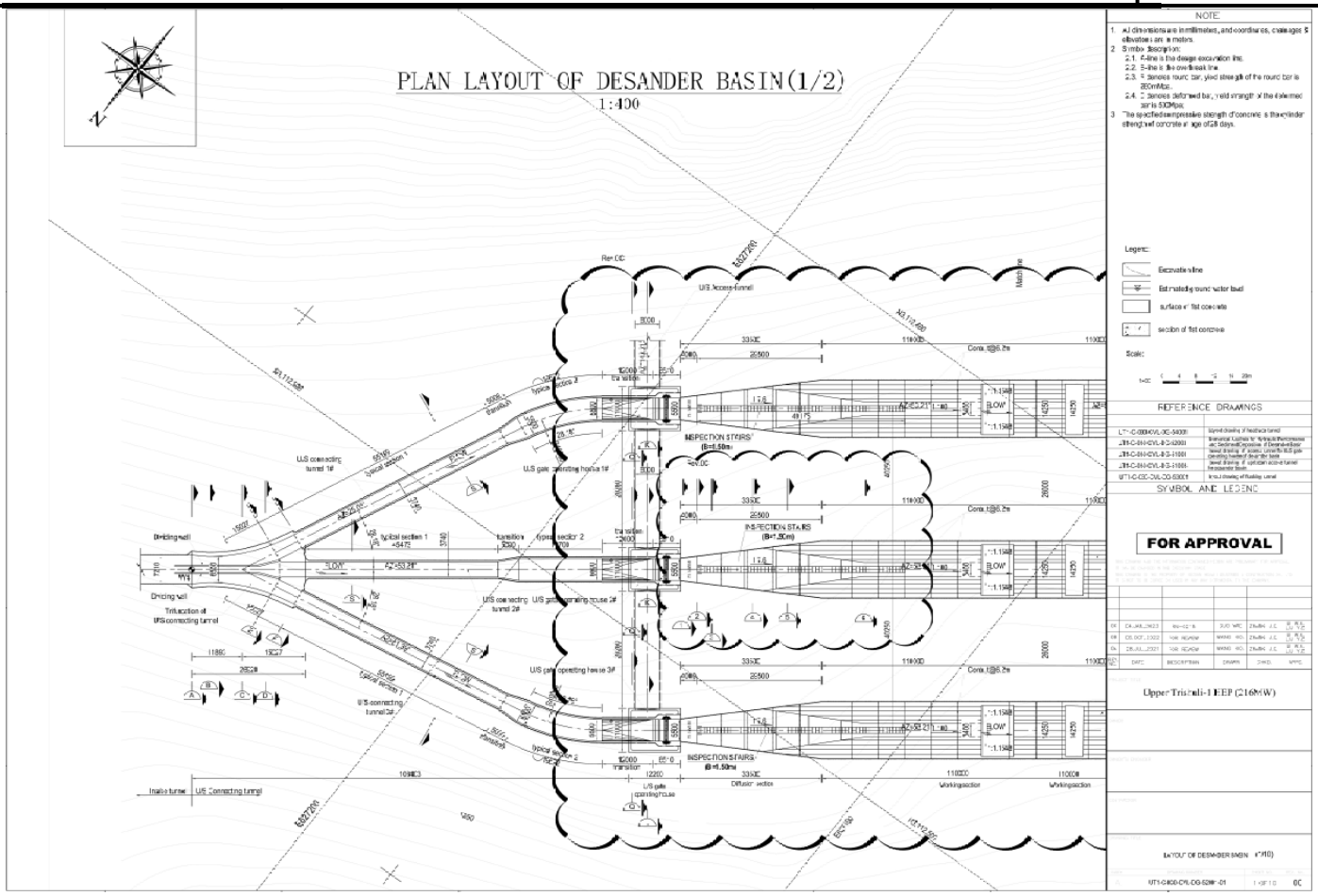
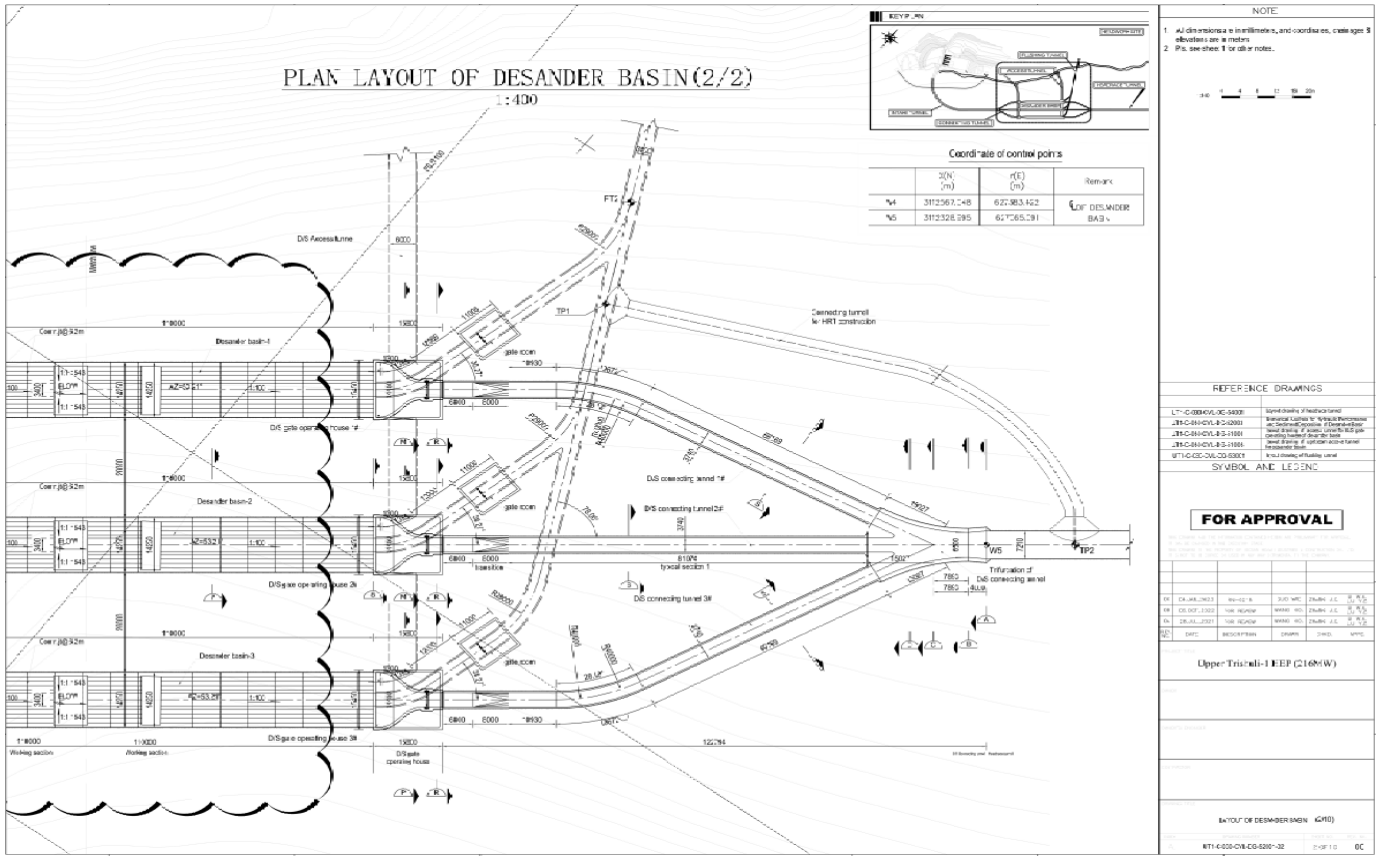


Figure 3.2: Cross-Section of Pipes


PLAN LAYOUT OF DESANDER BASIN(1/2)
1:400
NOTE:
Legend:
SYMBOL AND LEGENC
FOR APPROVAL
REFERENCE DRAWINGS
Upper Trishuli-1 HEP (216MW)


PLAN LAYOUT OF DESANDER BASIN(2/2)
1:400
Coordinate of control points
NOTE:
SYMBOL AND LEGENC
FOR APPROVAL
REFERENCE DRAWINGS
Upper Trishuli-1 HEP (216MW)

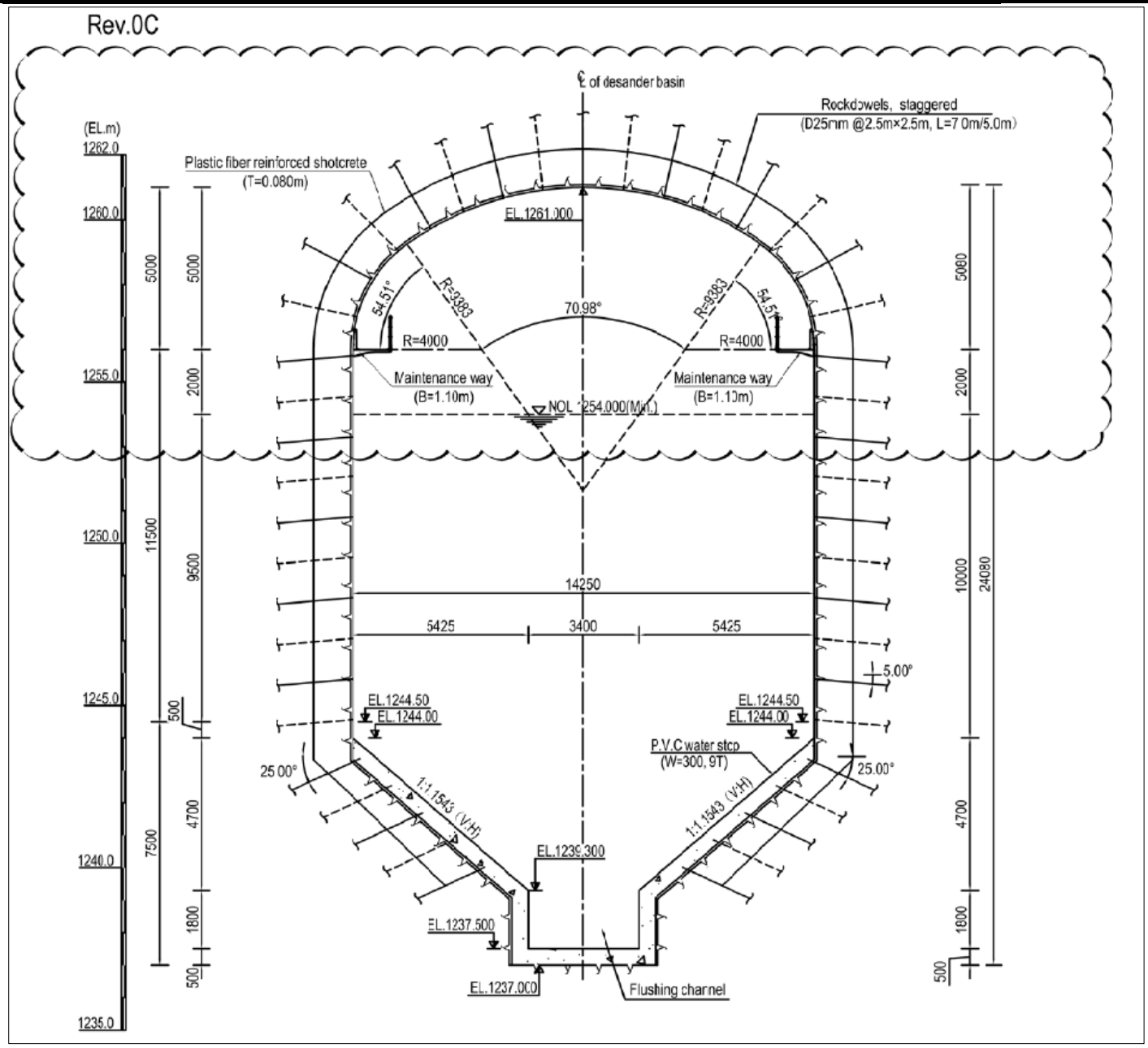
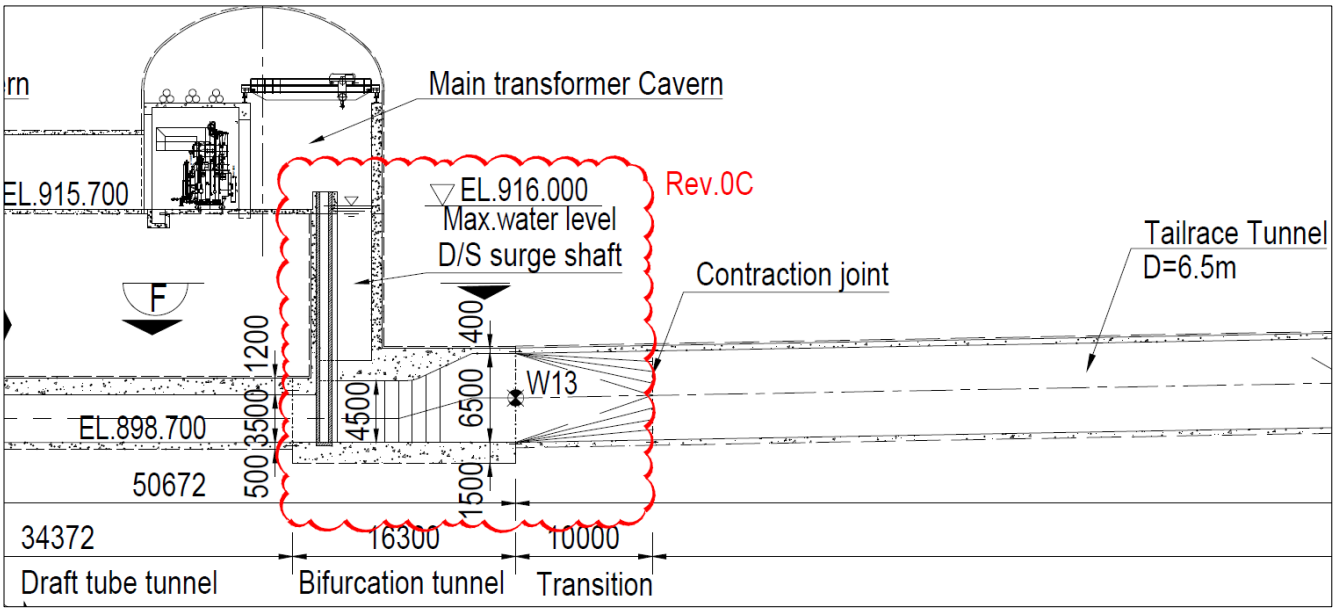
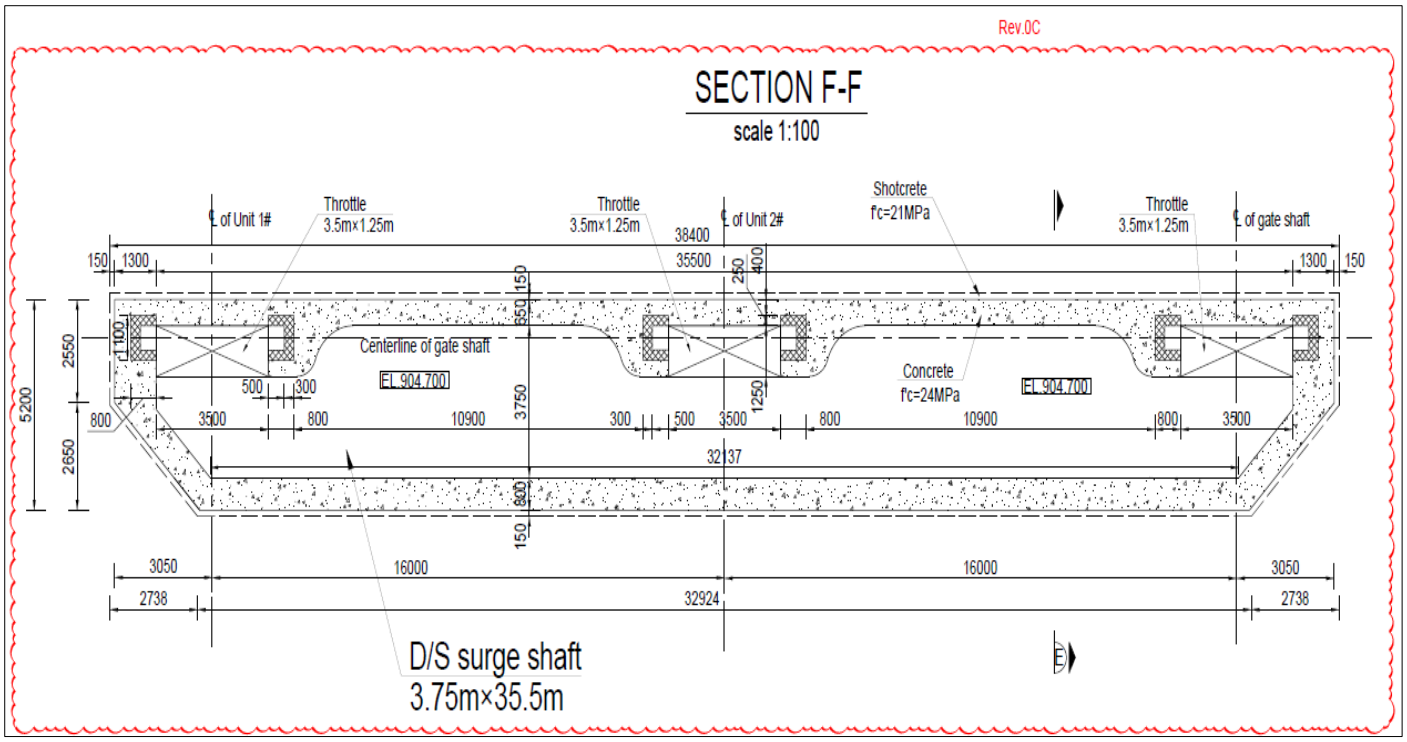


Figure 3.3: Drawings of Desander Basin

Rev.0E


rn
Main transformer Cavern
EL.915.700
EL.916.000
Max.water level
D/S surge shaft
Rev.0C
Contraction joint
Tailrace Tunnel
D=6.5m
F
1200
3500
500
EL.898.700
50672
4500
400
6500
W13
1500
34372
16300
10000
Draft tube tunnel
Bifurcation tunnel
Transition


Rev.0C
SECTION F-F
scale 1:100
℄ of Unit 1#
Throttle
3.5m×1.25m
Throttle
3.5m×1.25m
℄ of Unit 2#
Shotcrete
f'c=21MPa
Throttle
3.5m×1.25m
℄ of gate shaft
38400
35500
150
1300
1300
150
250
400
650
150
100
2550
5200
2650
Centerline of gate shaft
EL.904.700
500
300
Concrete
f'c=24MPa
EL.904.700
3750
1250
800
3500
800
10900
300
500
3500
800
10900
800
3500
32137
800
150
3050
16000
16000
3050
2738
32924
2738
D/S surge shaft
3.75m×35.5m

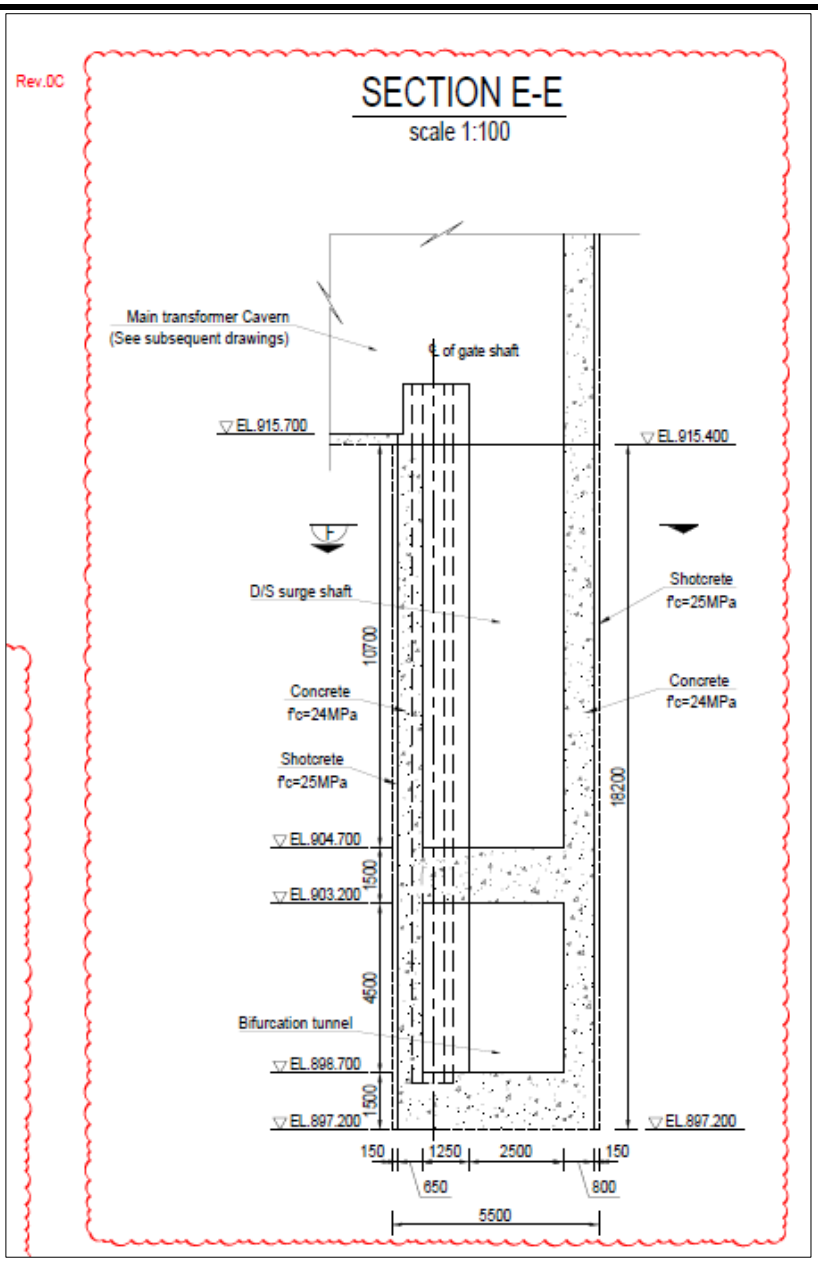
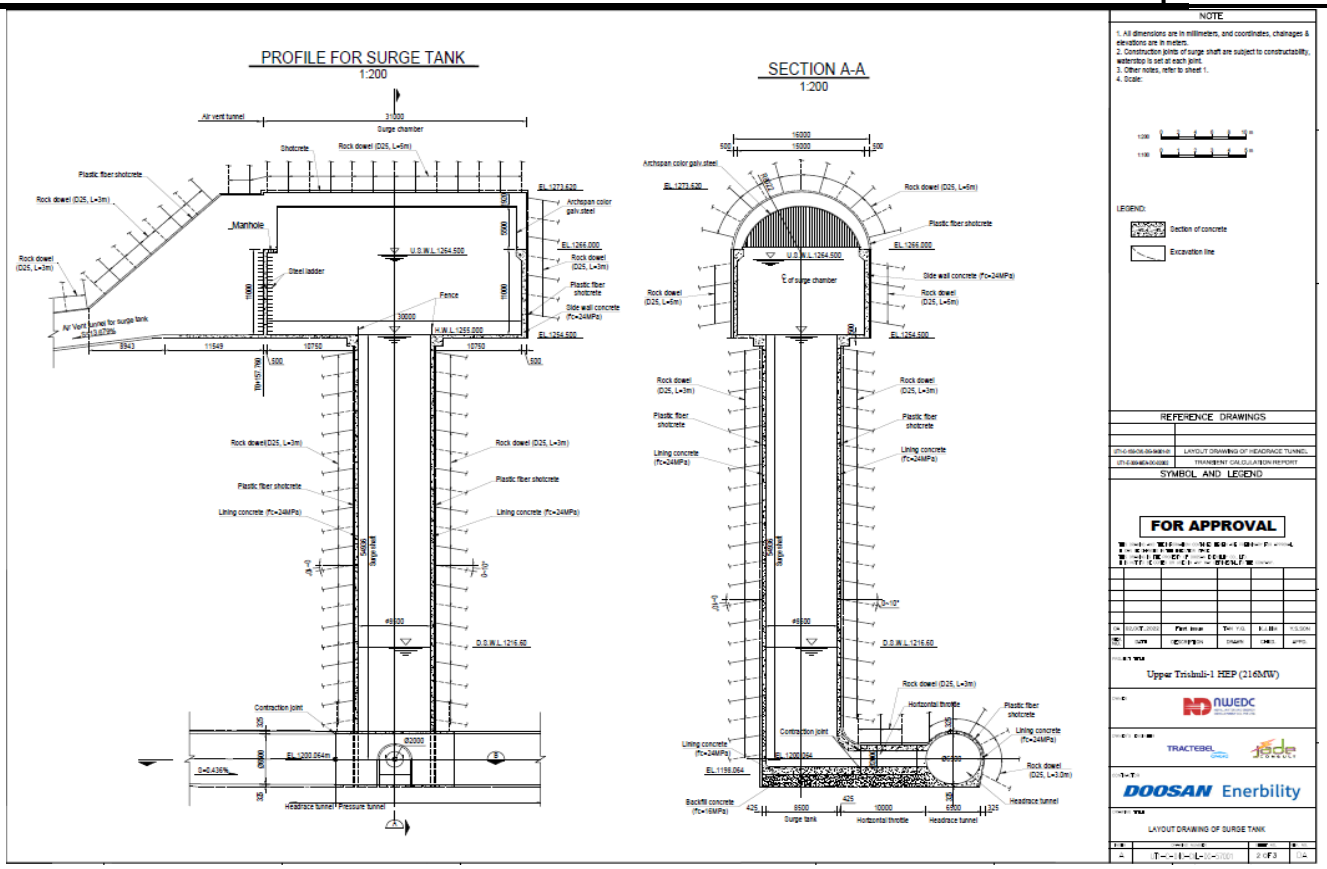


Figure 3.4: Downstream Surge Shaft

Rev.0E



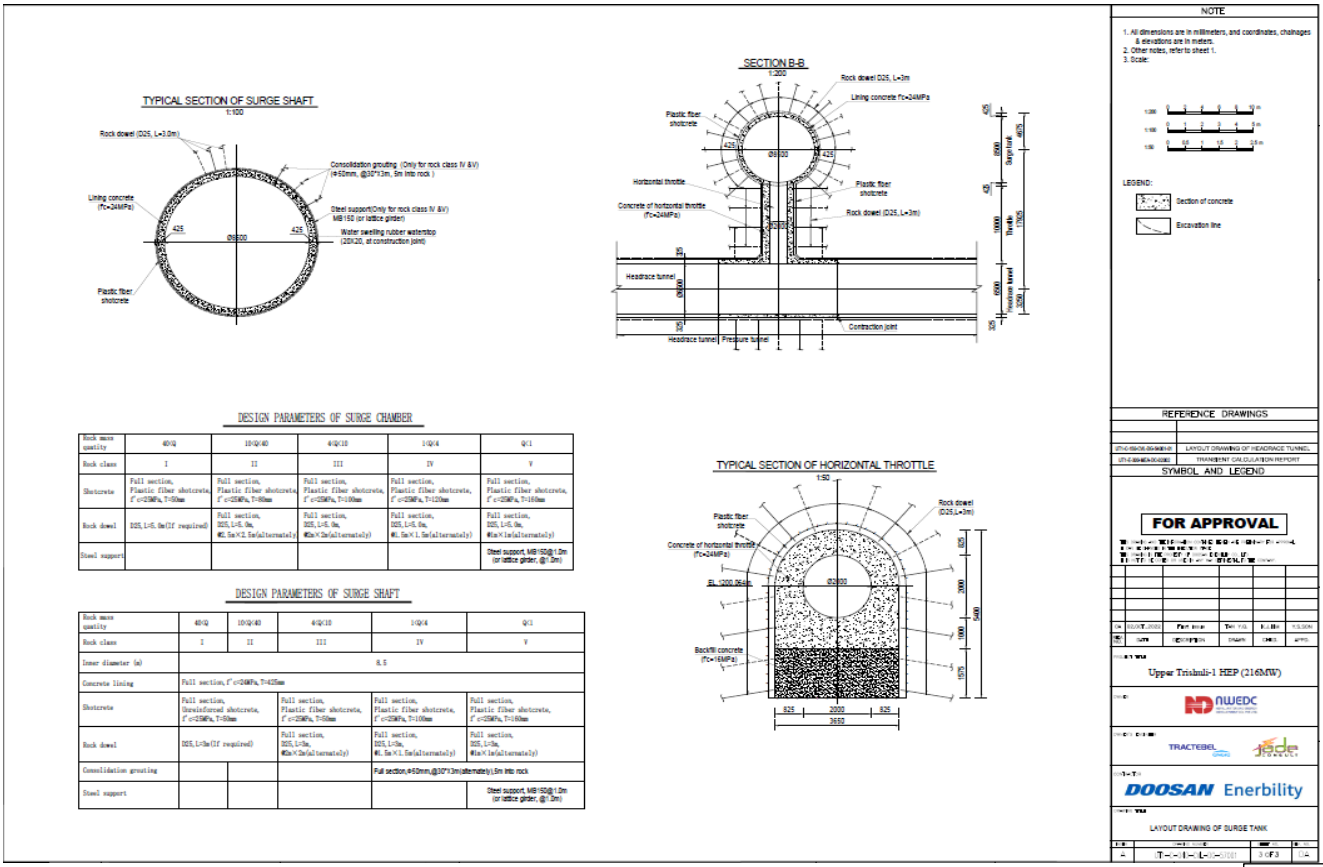


Figure 3.5: Upstream Surge Tank

Rev.0E

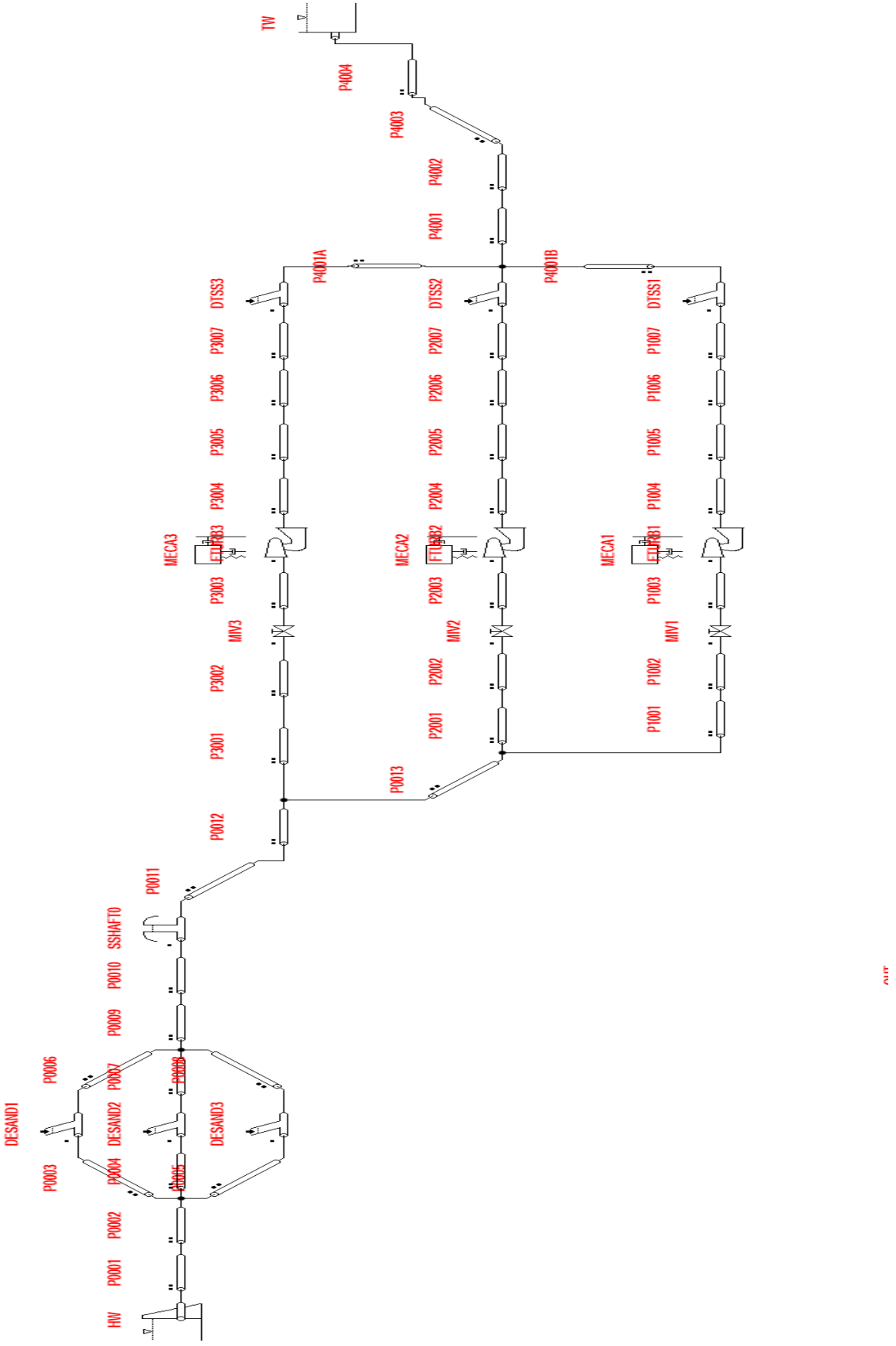


Figure 3.6: Sketch of simulation model

Rev.0E

Pipe Name [-]	Pipe Length, L [m]	Pipe Diameter, D [m]	Hydraulic Diameter, Dh [m]	Hydraulic Area, Ah [m2]	Elevation Pipe, Zin [masl]	Elevation Pipe, Zout [masl]	a [m/s]	λ [1]	Description [-]
P0001	30	6.5	0	0	1250.25	1250.25	1000	0.15083	Intake
P0002	242	7.21	0	0	1250.25	1247.75	1000	0.09132	Intake Tunnel
P0003	105	3.74	0	0	1247.75	1247.75	1000	0.01560	Desander Intake 1
P0004	95	3.74	0	0	1247.75	1247.75	1000	0.01558	Desander Intake 2
P0005	105	3.74	0	0	1247.75	1247.75	1000	0.01558	Desander Intake 3
P0006	105	3.74	0	0	1248.27	1241.47	1000	0.04065	Desander Outlet 1
P0007	95	3.74	0	0	1248.27	1241.47	1000	0.04493	Desander Outlet 2
P0008	105	3.74	0	0	1248.27	1241.47	1000	0.04065	Desander Outlet 3
P0009	27	6.5	0	0	1241.59	1241.47	964	0.54563	Junction
P0010	9497	0	7.094	43.092	1241.47	1200.07	1000	0.03757	Headrace Tunnel
P0011	361	6.5	0	0	1200.07	907.50	1003	0.02384	Pressure Tunnel
P0012	70	4.8	0	0	907.50	906.42	972	0.04724	Penstock Tunnel D4.8
P0013	14.5	3.9	0	0	906.42	906.24	906	0.15369	Penstock Tunnel D3.9
P1001	45	2.8	0	0	906.24	906.00	1023	0.06614	Penstock Branch Pipe1
P1002	4	1.6	0	0	906.00	906.00	1000	0.01200	MIV Inlet 1
P1003	8	1.58	0	0	906.00	906.00	1000	0.01200	Spiral Unit 1
P1004	3.8	1.9	0	0	905.41	901.62	950	0.01200	DT Cone 1
P1005	11	2.4	0	0	901.62	899.80	917	0.01200	Draft Tube 1
P1006	4	0	3.41	9.133	899.80	900.45	1000	0.02799	Draft Tube Tunnel1 Transition
P1007	36.5	0	3.631	12.07	900.45	900.45	1014	0.26448	Draft Tube Tunnel1
P2001	32	2.8	0	0	906.24	906.00	1000	0.09301	Penstock Branch Pipe2
P2002	4	1.6	0	0	906.00	906.00	1000	0.01200	MIV Inlet 2
P2003	8	1.58	0	0	906.00	906.00	1000	0.01200	Spiral Unit 2
P2004	3.8	1.9	0	0	905.41	901.62	950	0.01200	DT Cone 2
P2005	11	2.4	0	0	901.62	899.80	917	0.01200	Draft Tube 2
P2006	4	0	3.41	9.133	899.80	900.45	1000	0.02799	Draft Tube Tunnel2 Transition
P2007	36.5	0	3.631	12.07	900.45	900.45	1014	0.26448	Draft Tube Tunnel2
P3001	41	2.8	0	0	906.42	906.00	1025	0.07259	Penstock Branch Pipe3
P3002	4	1.6	0	0	906.00	906.00	1000	0.01200	MIV Inlet 3
P3003	8	1.58	0	0	906.00	906.00	1000	0.01200	Spiral Unit 3
P3004	3.8	1.9	0	0	905.41	901.62	950	0.01200	DT Cone 3
P3005	11	2.4	0	0	901.62	899.80	917	0.01200	Draft Tube 3
P3006	4	0	3.41	9.133	899.80	900.45	1000	0.02799	Draft Tube Tunnel3 Transition
P3007	36.5	0	3.631	12.07	900.45	900.45	1014	0.26448	Draft Tube Tunnel3
P4001	6	6.5	0	0	900.95	901.95	750	0.09623	Common TRT Bifurcation Tunnel
P4001A	1	10	0	0	901.95	901.95	250	0.00577	Dummy pipe
P4001B	1	10	0	0	901.95	901.95	250	0.00577	Dummy pipe
P4002	216	6.5	0	0	901.95	905.69	1000	0.02965	Common TRT
P4003	21.4	6.5	0	0	905.69	913.25	1070	0.06932	Common TRT inclined part
P4004	23.8	6.5	0	0	913.25	913.25	992	0.02620	Common TRT Outlet

Table 3.1: Data of waterway system

Rev.0E

3.2 Surge Tank

3.2.1 Surge Tank at Upstream

Rev.0E

Surge Tank at the end of Head race tunnel has been modelled as below.

Elevation [m]	Area [m^2]
1200.064	56.745
1255.000	56.745
1255.000	450.00
1264.500	450.00

A short horizontal pipe of 10.0m length and 2.0m diameter has been modelled as orifice.

For the calculation purpose Orifice discharge coefficient Cd = 0.7 has been considered.

Size of the surge tank has been verified regarding the Thoma Criterion. For details refer 'ANNEXURE-2'.

3.2.2 Surge Shaft at Downstream

Rev.0E

A common surge shaft at transformer cavern has been modelled as surge tank at downstream side.

Elevation [m]	Area [m^2]
904.70	120.0
917.00	120.0

Due to calculation tool limitation and to simplify, separate surge shaft at the end of individual draft tube tunnel has been simulated with equivalent surge shaft cross-sectional area 40m2. This will not have impact on end calculation results.

At elevation 903.2m, draft tube gate opening of 3.5m x 1.25m has been modelled as orifice with 4.375m^2 cross sectional area.

For the calculation purpose Orifice discharge coefficient Cd = 0.7 has been considered.

3.2.3 Desander Basins

Rev.0E

3 nos. desander basins each of 14.25mX10.0mX110.0m (WxHxL) has been modelized as surge tank at nodes DESAND01/DESAND02 and DESAND03.

3.3 Motor-Generator

The moment of inertia of the complete rotor including shaft and hydraulic runner is assumed to be WR^2 = 187.5 tm^2.

3.4 Main Inlet Valves

The main inlet valves are of Spherical type. The nominal diameter is = 1.6 m.

3.4.1 Opening and closing law of MIV

MIV opening and closing time to be 150s maximum as per contract.

130s time both for opening and closing has been finalized to keep runner under pressure and maximum upsurge level at Upstream surge tank within acceptable limit.

The opening and the closing are done linear.

Linear, opening time from 0 to 100% Tg = 130 [s]
Linear, closing time from 100 to 0% Tf = 130 [s]

3.5 Distributor

The guide vanes are connected to two servomotors via a regulating ring. The modeled kinematic considers the relation between servomotor stroke and guide vane opening.

Guide vane closing and opening times are selected such that critical parameters like speed rise and pressure rise remain within contractual guaranteed limits.

The closing laws are described in following Table 3.2 and shown in the Figure 3.4. Rev.0E

	T_f (Time, Fast slope)	Th (Time, Slow slope)	Yh (Slope change)
	[s]	[s]	[%]
Quick shut down triggered by electrical reason (QSD-E)	8.5	12.5	35

Table 3.2: Guide vane closing times

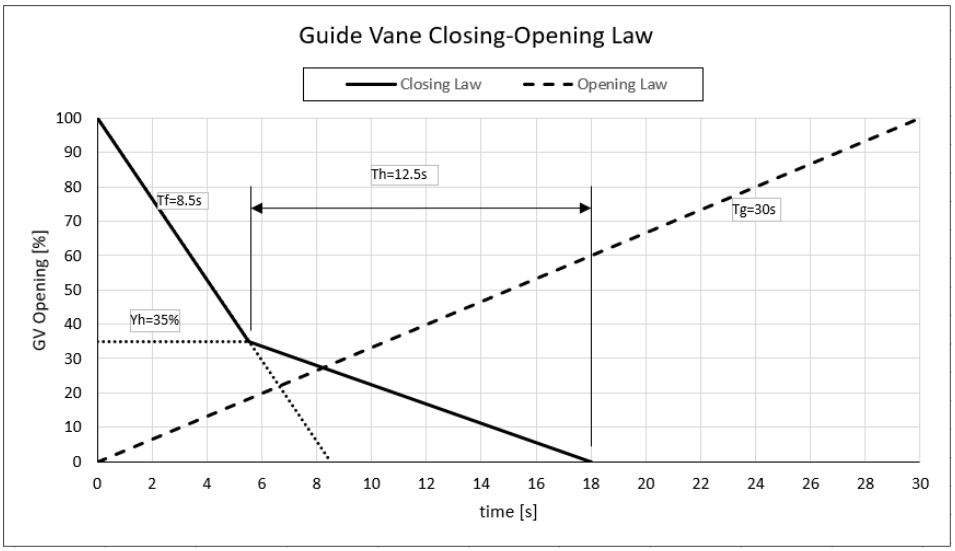


Figure 3.7: Guide vane Closing-Opening Law

1st Slope, Fast Closing (Tf): Guide vane will close in 8.5s.

2nd Slope, Slow Closing (Th): Guide vane will close in 12.5s.

Slope changes from 1st slope to 2nd slope (Yh): at 35% of Guide vane opening

The guide vane opening time (Tg) from 0 to 100% Load = 30s.

4 MANEUVER EXPLANATIONS

To ensure safe operation potential critical maneuvers have been analyzed.

4.1 Load Rejection / Quick Shut Down triggered by electric reason (QSD-E)

At trip time equal 2 second, the circuit breaker is opened and closing command is given to the guide vane servo motor. The applied closing law as described in chapter 3.5 is depending on the prevailing turbine operation mode.

4.2 Emergency Shut Down (ESD)

At trip time equal 2 second, the circuit breaker is opened and closing command is given to the Main Inlet Valve as guide vane servo motors fail to close. The applied closing law as described in chapter 3.4.1 is applied.

4.3 Loading of the turbine (LA)

At time equal 2 seconds, the loading of the synchronized turbine at speed no load condition starts by guide vane opening according to opening law.

4.4 Runaway (Runaway)

At a trip time equal to 2 seconds, the circuit breaker is opened but the guide vane servo motor position is kept. This leads to runaway of the unit.

4.5 Loading of the turbine (LA) followed by Load Rejection / Quick Shut Down (QSD-E)

Rev.0D

At a trip time equal to 2 seconds, Load Acceptance from Speed No Load condition to full output followed by Load Rejection.

Rev.0D

4.6 Load Rejection / Quick Shut Down (QSD-E) + Speed No Load (SNL) + Loading of the turbine (LA)

At a trip time equal 2 second, Load Rejection from full load to Speed No Load condition followed by Load Acceptance to full load.

5 CALCULATION RESUTLS

The presented results are calculation results without any addition for modelling and calculation uncertainty.

Following abbreviations are used:

QSD-E…	Quick shut down triggered by electrical reason
ESD…	Emergency shut down by MIV, Turbine Guide Vanes remain open
Runaway…	Runaway
LA…	Load acceptance after speed no load
LR…	Load rejection (QSD-E)
SNL…	Speed No Load, unit running at Rated speed and Zero load
MIV…	Main inlet valve
Hr…	Rated net head
Hmax…	Maximum net head
FRL…	Maximum head water level
TWLmax…	Maximum tail water level
TWLmin…	Minimum tail water level
100%P…	Rated power (74.5 MW)
Unit-#…	Unit running, Unit-1/Unit-2/Unit-3
All Units…	All 3 units
CLOSE…	Specified unit is not running
DTSS…	Downstream Surge Gallery at Transformer cavern
USSS…	Upstream Surge Tank at HRT end
T1/T2/T3…	Unit Turbine 1/2/3
n [rpm]…	Speed in rpm
Q [m3/s]…	Discharge in m3/s
y [%]…	Guide vane opening in %
h_Spiral…	Pressure in spiral casing in [mwc]
h_DT…	Pressure in draft tube inlet (runner outlet) in [mwc]
SSHAFT_level…	Water level in Upstream surge tank in [masl]
DTSHAFT_level…	Water level in Downstream draft tube gallery [masl]
DESAND_level…	Water level in desander tunnel [masl]

Rev.0D

All simulated cases with initial conditions and calculated results are listed in the following table.

Simulation Number	Head Water Level	Tail Water Level	Initial Values				Calculated Values										Load Case
			Power	Head	Flow	Speed	Speed	Pressure at Spiral/MIV Inlet		Pressure at Runner Outlet	Surge shaft water Level		Downstrem Gallery Water Level		Desander Water Level		
							max	min	max	min	min.	max.	min	max	min	max	
	masl	masl	MW	m	m3/s	rpm	rpm	mwc		mwc	m		m		m		
FR04																	
Quick Shutdown cases (Load Rejection)																	
001	1255.00	914.11	74.5	327.00	24.70	428.57	611.2	328.38	377.3	2.26	1244.30	1263.10	909.04	917.12	1254.20	1255.70	QSD-E 3U Hr 100%P
002	1255.00	912.41	74.5	339.00	23.90	428.57	593.4	338.71	364.5	0.09	1247.70	1259.00	910.64	914.02	1254.60	1255.30	QSD-E Unit-1 Hmax 100%P
003	1255.00	912.41	74.5	339.00	23.90	428.57	592.3	338.83	363.7	0.27	1247.70	1259.00	910.64	914.02	1254.60	1255.30	QSD-E Unit-3 Hmax 100%P
004	1255.00	914.11	37.2	343.00	12.40	428.57	542.6	344.1	359.9	1.61	1250.10	1257.40	910.27	912.08	1254.70	1255.20	QSD-E Unit-1 Hmax 50%P
Runaway cases (Guide Vanes remain open)																	
005	1255.00	914.11	74.5	327.00	24.70	428.57	652.2	328.38	356.6	4.08	1245.50	1259.40	910.77	917.02	1254.20	1255.30	Runaway All Units 100%P Hrated
006	1255.00	914.11	74.5	328.00	24.70	428.57	**659.3**	328.38	371.0	2.53	1244.00	1262.00	909.60	917.10	1254.20	1255.60	Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated
007	1255.00	914.11	74.5	329.00	24.70	428.57	659.1	328.38	372.0	2.47	1244.00	1262.00	909.60	917.10	1254.20	1255.60	Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated
008	1255.00	912.41	74.5	339.00	23.90	428.57	645.8	338.71	353.4	2.36	1249.60	1257.50	911.20	913.54	1254.60	1255.20	Runaway Unit-1 100%P Hmax
009	1255.00	912.41	74.5	339.00	23.90	428.57	645.5	338.83	352.9	2.35	1249.60	1257.50	911.21	913.55	1254.60	1255.20	Runaway Unit-3 100%P Hmax
Emergency Shutdown cases (Shutdown by MIV, Turbine Guide Vanes remain open)																	
010	1255.00	914.11	74.5	328.00	24.70	428.57	647.2	329.46	380.9	1.96	1244.90	1262.10	910.70	917.03	1254.20	1255.70	ESD All Units 100%P Hrated
011	1255.00	912.41	74.5	339.00	23.60	428.57	638.0	342.37	360.7	1.12	1248.40	1258.50	911.17	913.56	1254.60	1255.30	ESD Unit-1 100%P Hmax
012	1255.00	912.41	74.5	339.00	23.60	428.57	637.4	339.89	362.6	1.08	1248.40	1258.50	911.18	913.56	1254.60	1255.30	ESD Unit-3 100%P Hmax
Load Acceptance cases																	
0030	1255.00	910.00	0.00	345.00	1.72	428.57	428.57	303.65	350.2	-0.66	1219.60	1255.00	907.41	914.12	1253.70	1255.00	LA All Units 100%P FRL TWL-910m
0031	1255.00	910.00	0.00	345.00	1.72	428.57	428.57	327.99	349.0	0.82	1242.50	1256.30	908.74	911.44	1254.50	1255.10	LA Unit-1 CLOSE Unit-2&3 100%P FRL TWL-910m
0032	1255.00	910.00	0.00	345.00	1.72	428.57	428.57	322.75	350.1	0.26	1239.20	1255.30	908.22	912.46	1254.30	1255.00	LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m
0033	1255.00	910.00	0.00	345.00	1.72	428.57	428.57	320.12	350.1	0.82	1235.80	1255.00	908.74	912.46	1254.00	1255.00	LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m
0037	1255.00	914.11	0.00	341.00	1.72	428.57	428.57	304.18	349.8	4.28	1219.90	1255.00	912.29	917.11	1253.70	1255.00	LA All Units 100%P FRL TWL-914.11m
Load Acceptance followed by Load Rejection cases																	
0034	1255.00	910.00	0.00	345.00	1.72	428.57	**620.1**	303.65	**385.2**	**-2.68**	**1219.60**	**1263.30**	**905.42**	914.12	1253.70	**1255.80**	LA+LR All Units 0-100-0%P FRL TWL-910m
0035	1255.00	910.00	0.00	345.00	1.72	428.57	593.60	327.99	368.6	-2.56	1242.50	1259.20	907.67	912.08	1254.50	1255.40	LA+LR Unit-1 0-100-0%P CLOSE Unit-2&3 FRL TWL-910m
Load Rejection + Speed No Load + Load Acceptance cases																	
0036	1255.00	914.11	74.5	327.00	24.70	428.57	611.2	310.57	377.3	2.26	1224.50	1262.30	909.04	**917.13**	**1253.50**	1255.60	QSD-E+SNL+LA All Units 100%P Hrated

Table 5.1: Summary of simulation results

Rev.0E

Simulation Number	Head Water Level	Tail Water Level	Initial Values				Calculated Values				Load Case
			Power	Head	Flow	Speed	Surge shaft water Level		Downstrem Gallery Water Level		
							min.	max.	min	max	
	masl	masl	MW	m	m3/s	rpm	m		m		
FR04											
Upstream Surge Tank											
001	1255.00	914.11	74.5	327.00	24.70	428.57	1244.30	1263.10			QSD-E 3U Hr 100%P
0034	1255.00	910.00	0.00	345.00	1.72	428.57	**1219.60**	**1263.30**			LA+LR All Units 0-100-0%P FRL TWL-910m
0030	1255.00	910.00	0	345.00	1.72	428.57	**1219.60**	1255.00			LA All Units 100%P FRL TWL-910m
0036	1255.00	914.11	74.5	327.00	24.70	428.57	1224.50	1262.30			QSD-E+SNL+LA All Units 100%P Hrated
Downstream Surge Tank (DT Shaft)											
0037	1255.00	914.11	0	341.00	1.72	428.57			912.29	917.11	LA All Units 100%P FRL TWL-914.11m
0036	1255.00	914.11	74.5	327.00	24.70	428.57			909.04	**917.13**	QSD-E+SNL+LA All Units 100%P Hrated
0034	1255.00	910.00	0.00	345.00	1.72	428.57			**905.42**	914.12	LA+LR All Units 0-100-0%P FRL TWL-910m
0035	1255.00	910.00	0.00	345.00	1.72	428.57			907.67	912.08	LA+LR Unit-1 0-100-0%P CLOSE Unit-2&3 FRL TWL-910m

Table 5.2: Summary of simulation results for Surge Tanks

Rev.0E

6 CONCLUSIONS

Rev.0E

The calculated maximum speed rise during quick shut down (load rejection) is 620.0 rpm. The maximum speed rise remains below the guaranteed maximum allowed value for all calculated load cases and maneuvers.

The maximum runaway speed is calculated to be 659.3 rpm. The maximum runaway speed remains below the guaranteed maximum runaway speed for all calculated load cases and maneuvers.

The calculated maximum pressure in the spiral casing is 385.2 mwc during quick load rejection. The maximum pressure remains below the guaranteed maximum allowed pressure for all calculated load cases and maneuvers.

Andritz internal recommendation value of pressure at Runner Outlet is (-4.0m). For all load cases pressure at runner outlet is within this acceptable limit.

Surge Tank at Upstream

Maximum upsurge level reaches to 1263.3m and minimum down surge level reaches to 1219.6m.

Both maximum upsurge and minimum down surge calculated values are within given limits of 1264.5m and 1216.6m respectively.

Surge Gallery at Downstream

Maximum upsurge level reaches to 917.13m and minimum down surge level reaches to 905.42m.

Minimum down surge level is above the level of orifice 904.7m.

However, maximum upsurge level for many cases breaches the limit 916.0m.

Hence, downstream surge shaft level needs to be modified keeping sufficient margin over 917.13m.

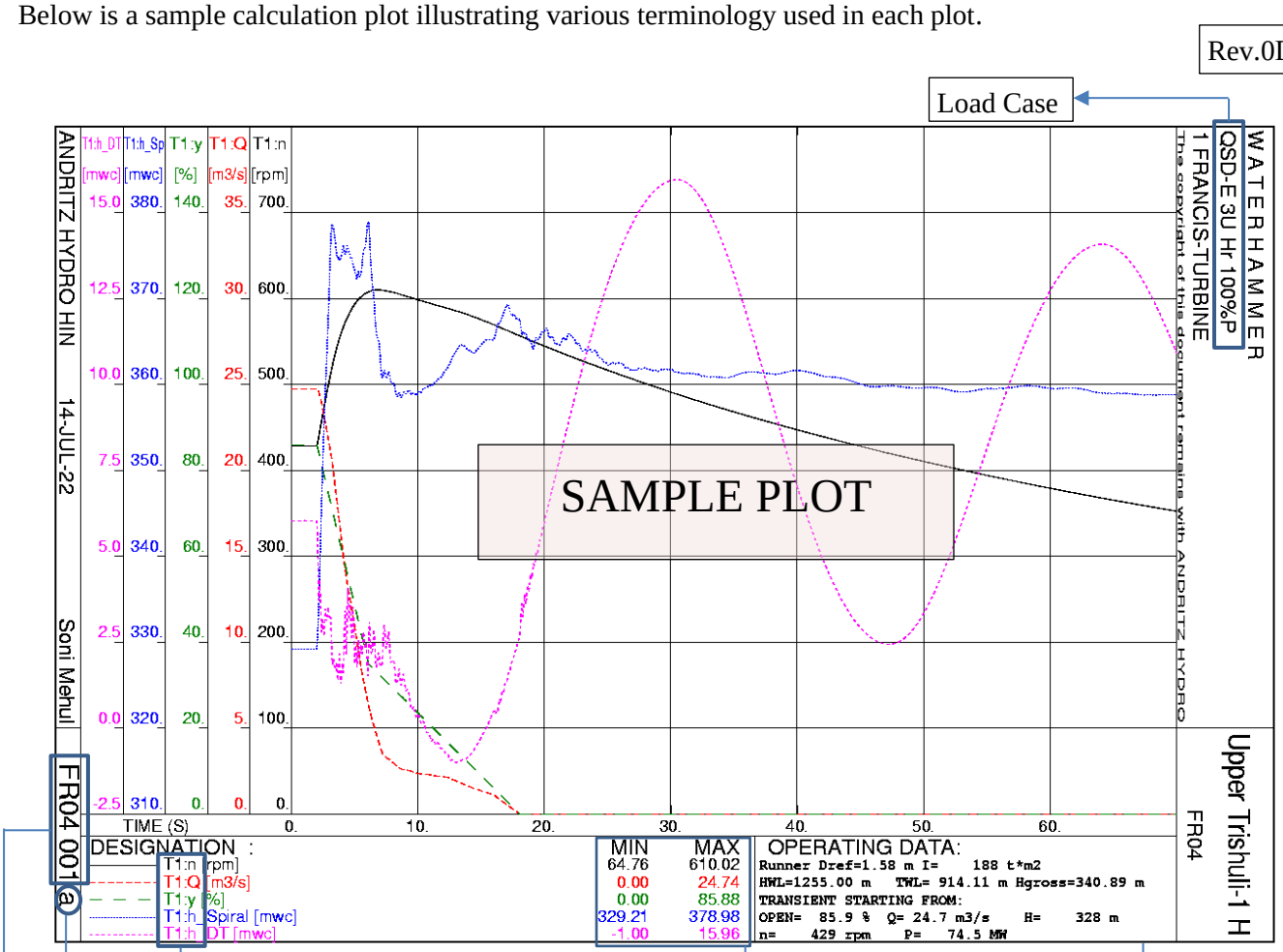
7 REFERENCES

Ref.1 www.powervision-eng.ch

8 ENCLOSURES

In the following, results of all simulated cases are presented as graphical plots over time and in tabular form.

Below is a sample calculation plot illustrating various terminology used in each plot.



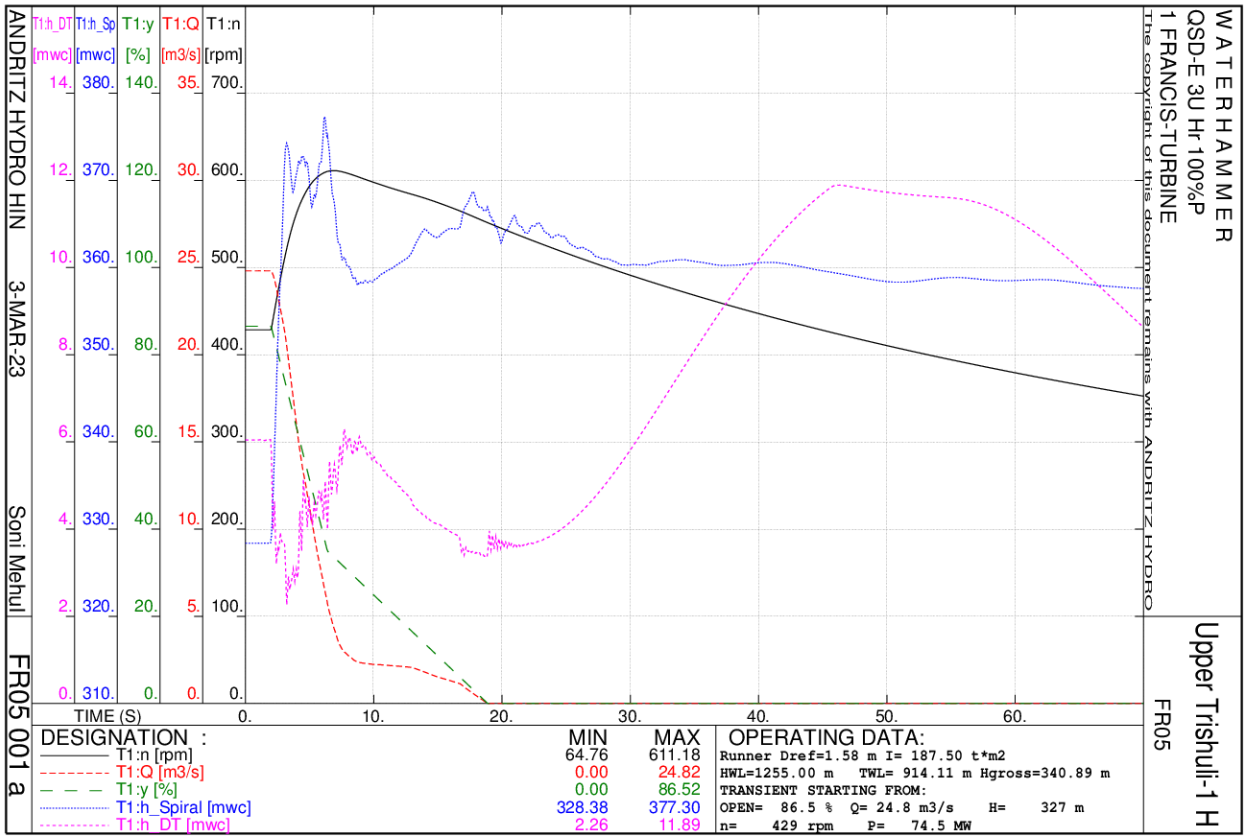
Parameters plotted.
Refer abbreviations description given in 'Section-5' page 20 for details

Machine data with its initial operating data.

Unit number.
'a' for Unit-1, 'b' for Unit-2,
'c' for Unit-3,
'd' for Surge shaft & Draft tube shaft,
'e' for Desander basin.

Calculation results.
Minimum and Maximum values of each parameter.

Simulation Number


WATERHAMMER
QSD-E 3U Hr 100%P
1 FRANCIS-TURBINE
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Upper Trishuli-1 H
FR05
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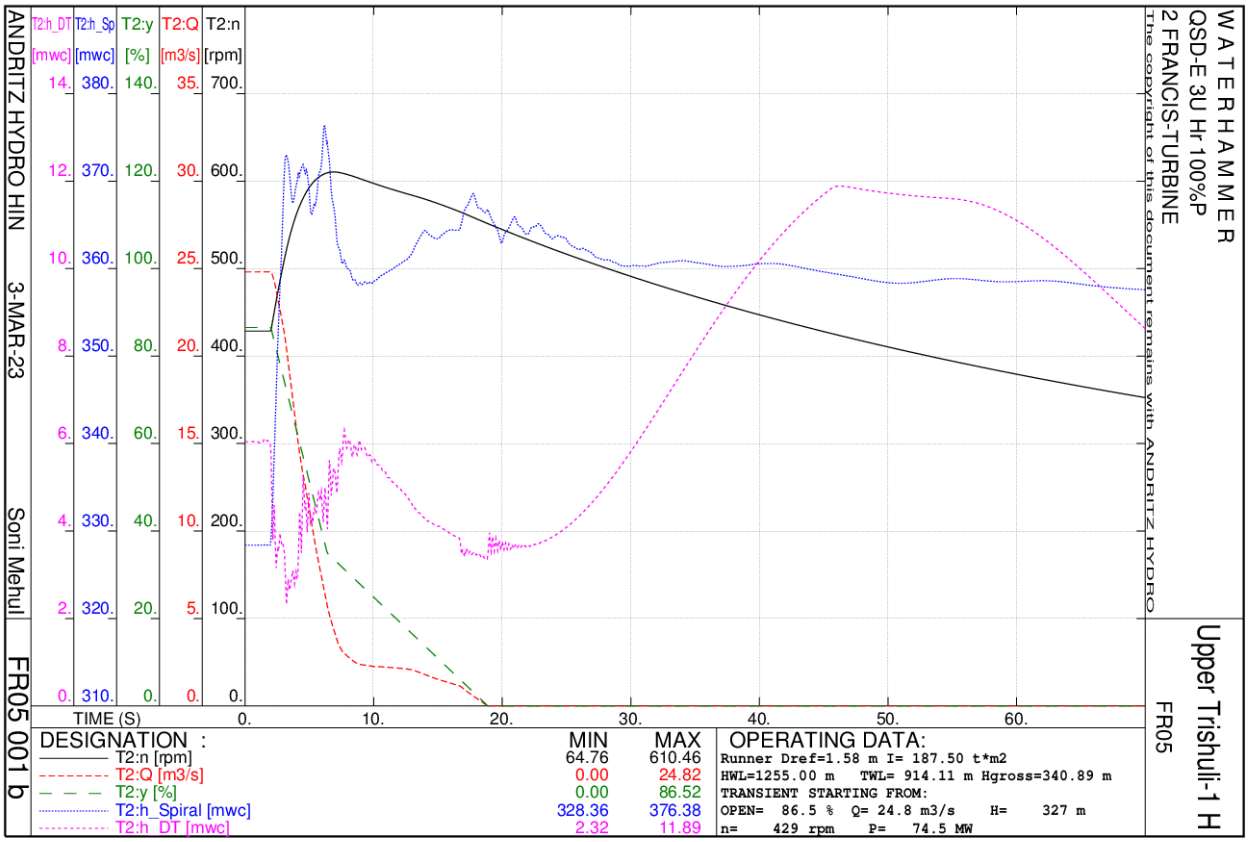
Soni Mehul
FR05 001 a
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 64.76 MAX 611.18
T1:Q [m3/s] 0.00 24.82
T1:y [%] 0.00 86.52
T1:h_Spiral [mwc] 328.38 377.30
T1:h_DT [mwc] 2.26 11.89
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E 3U Hr 100%P
2 FRANCIS-TURBINE
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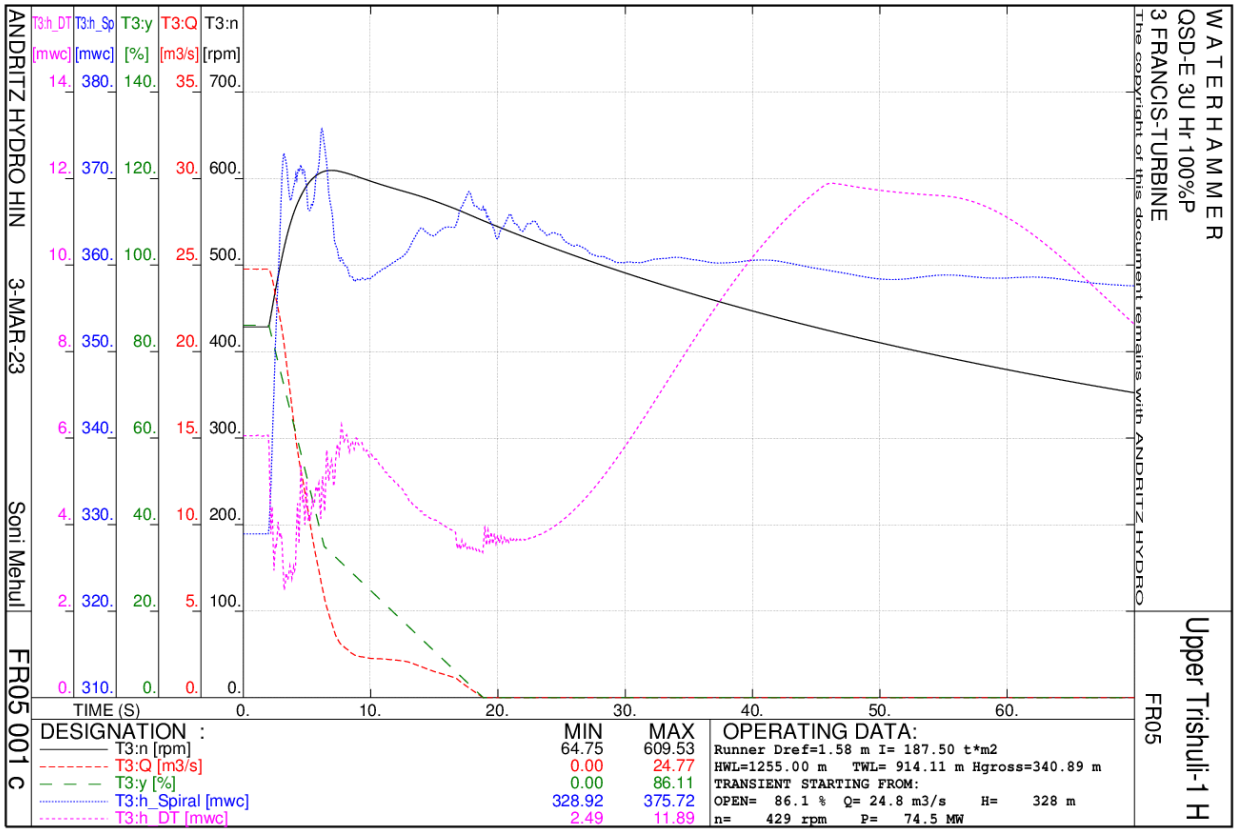
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 001 b
T2:h_DT [mwc]
T2:h_Sp [mwc]
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
TIME (S)
DESIGNATION :
T2:n [rpm] MIN 64.76 MAX 610.46
T2:Q [m3/s] 0.00 24.82
T2:y [%] 0.00 86.52
T2:h_Spiral [mwc] 328.36 376.38
T2:h_DT [mwc] 2.32 11.89
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E 3U Hr 100%P
3 FRANCIS-TURBINE
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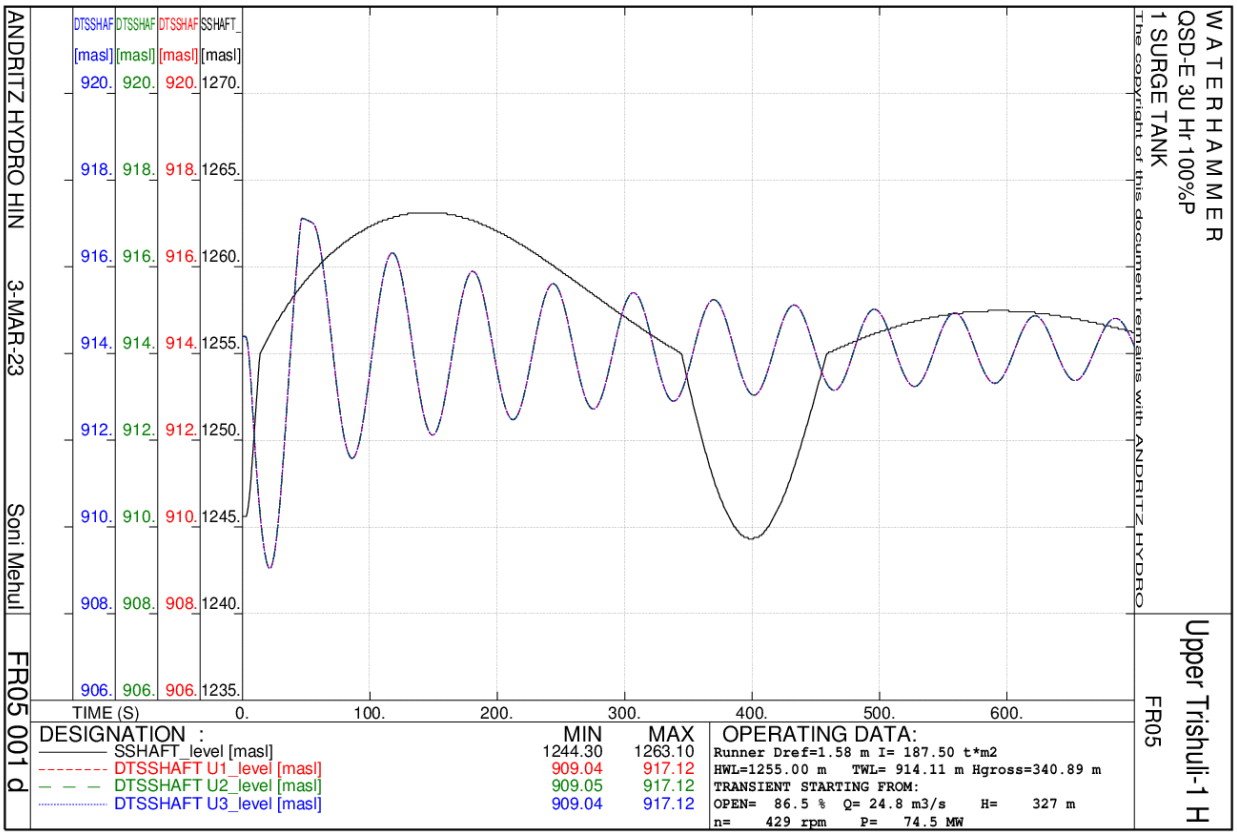
FR05 001 c
Upper Trishuli-1 H
FR05
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm] MIN 64.75 MAX 609.53
T3:Q [m3/s] 0.00 24.77
T3:y [%] 0.00 86.11
T3:h_Spiral [mwc] 328.92 375.72
T3:h_DT [mwc] 2.49 11.89
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.1 % Q= 24.8 m3/s H= 328 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E 3U Hr 100%P
1 SURGE TANK
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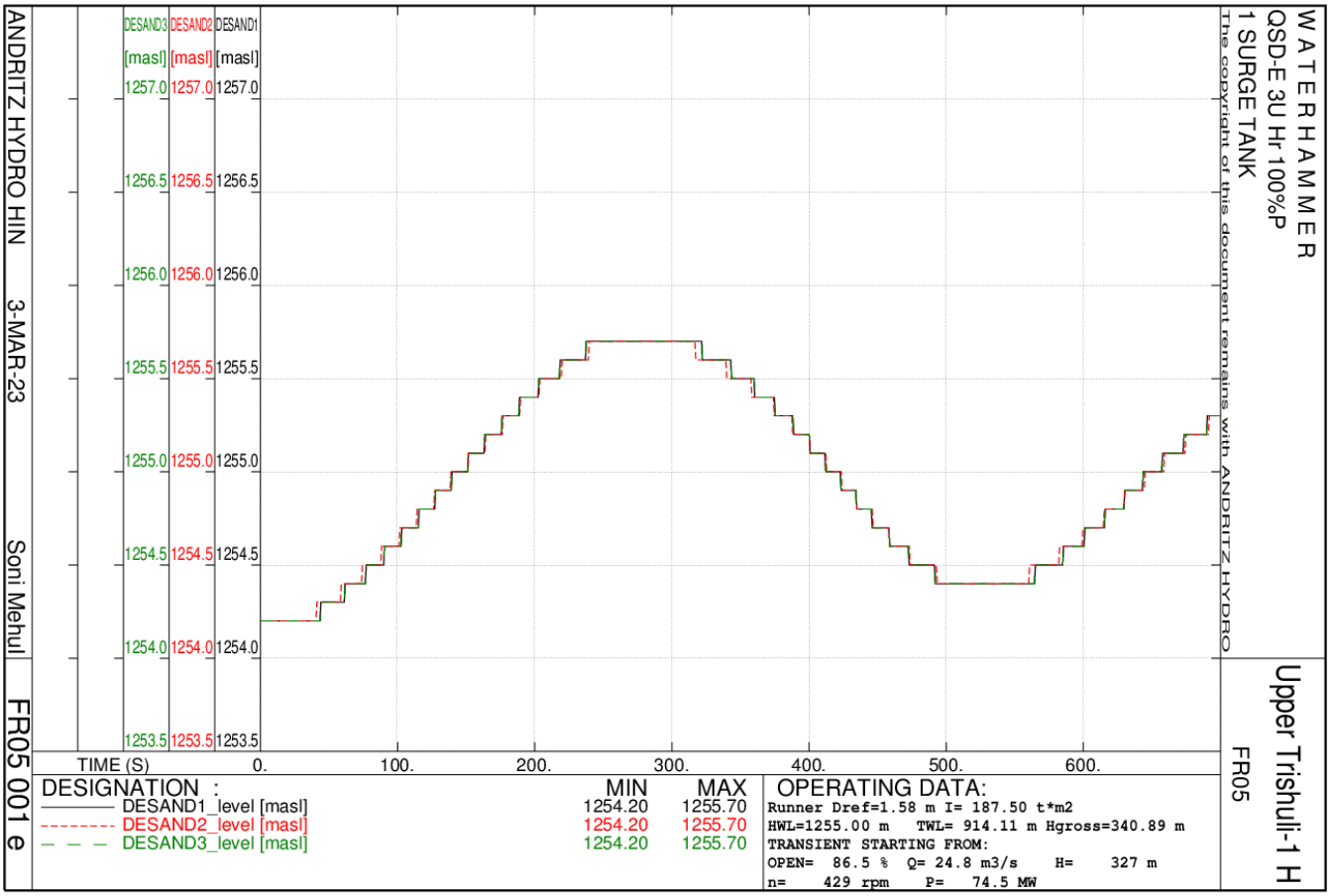
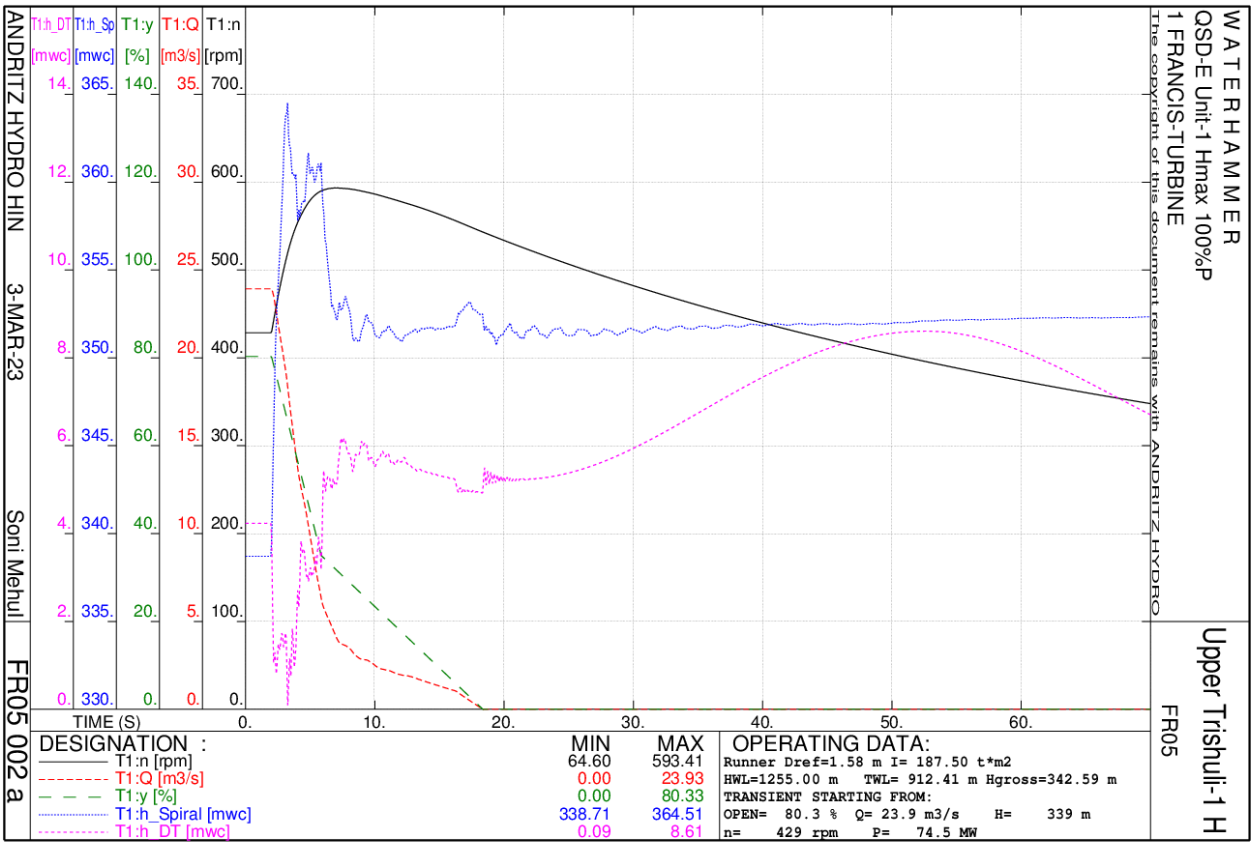
FR05
DTSSHAF [masl]
DTSSHAF [masl]
DTSSHAF [masl]
SSHAFT_ [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1244.30 MAX 1263.10
DTSSHAFT U1_level [masl] 909.04 917.12
DTSSHAFT U2_level [masl] 909.05 917.12
DTSSHAFT U3_level [masl] 909.04 917.12
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



FR05 001 QSD-E 3U Hr 100%P


WATERHAMMER
QSD-E Unit-1 Hmax 100%P
1 FRANCIS-TURBINE
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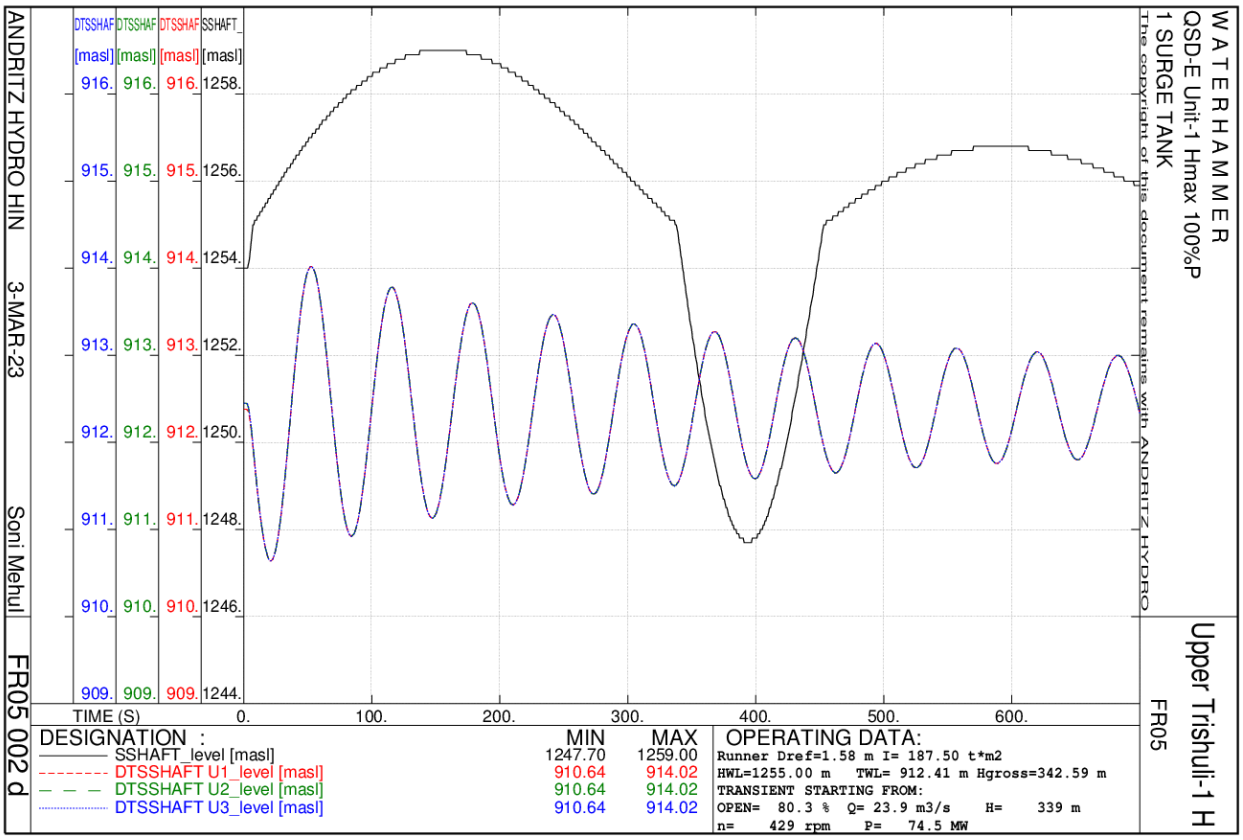
FR05 002 a
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 64.60 MAX 593.41
T1:Q [m3/s] 0.00 23.93
T1:y [%] 0.00 80.33
T1:h_Spiral [mwc] 338.71 364.51
T1:h_DT [mwc] 0.09 8.61
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E Unit-1 Hmax 100%P
1 SURGE TANK
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FR05
ANDRITZ HYDRO HIN
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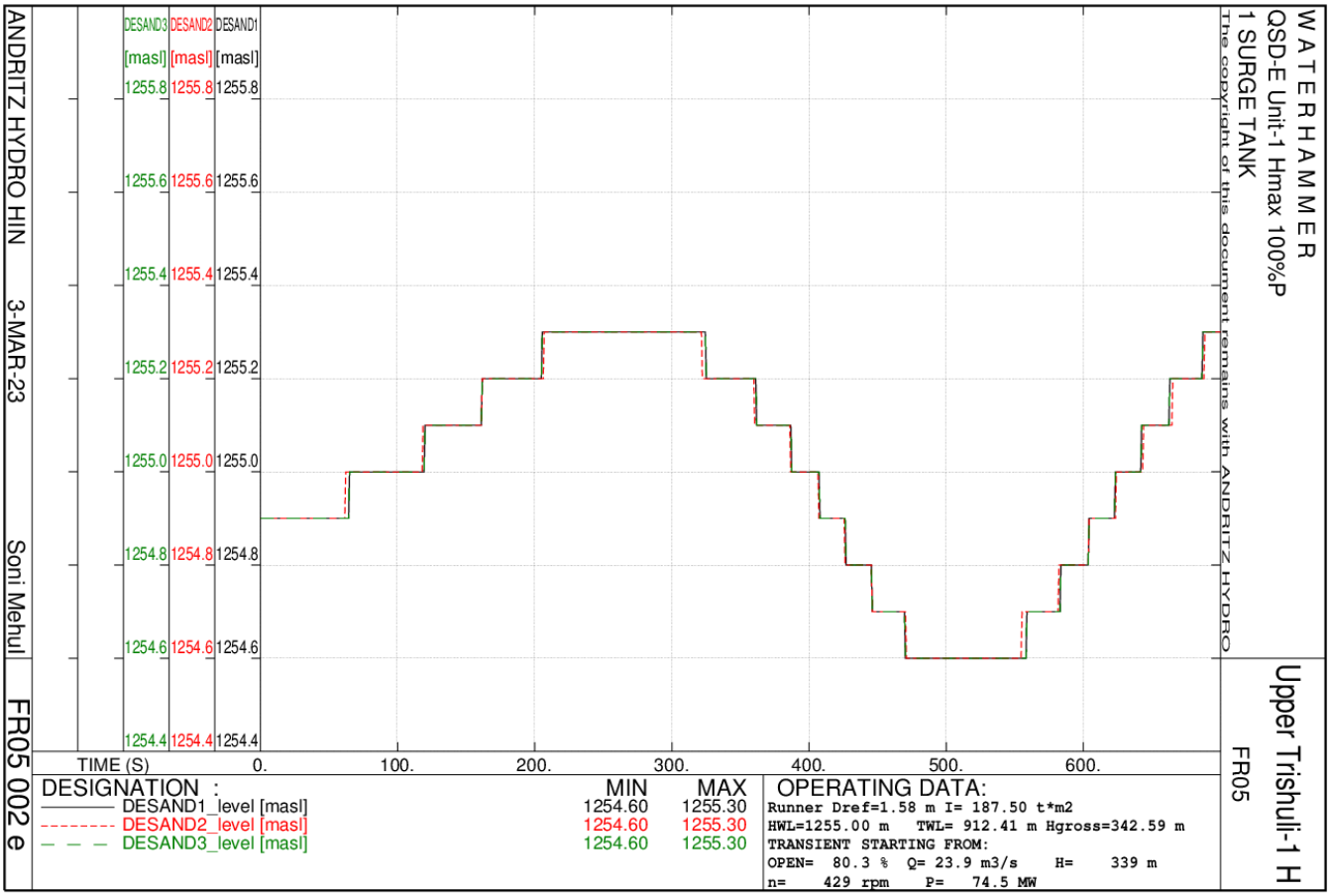
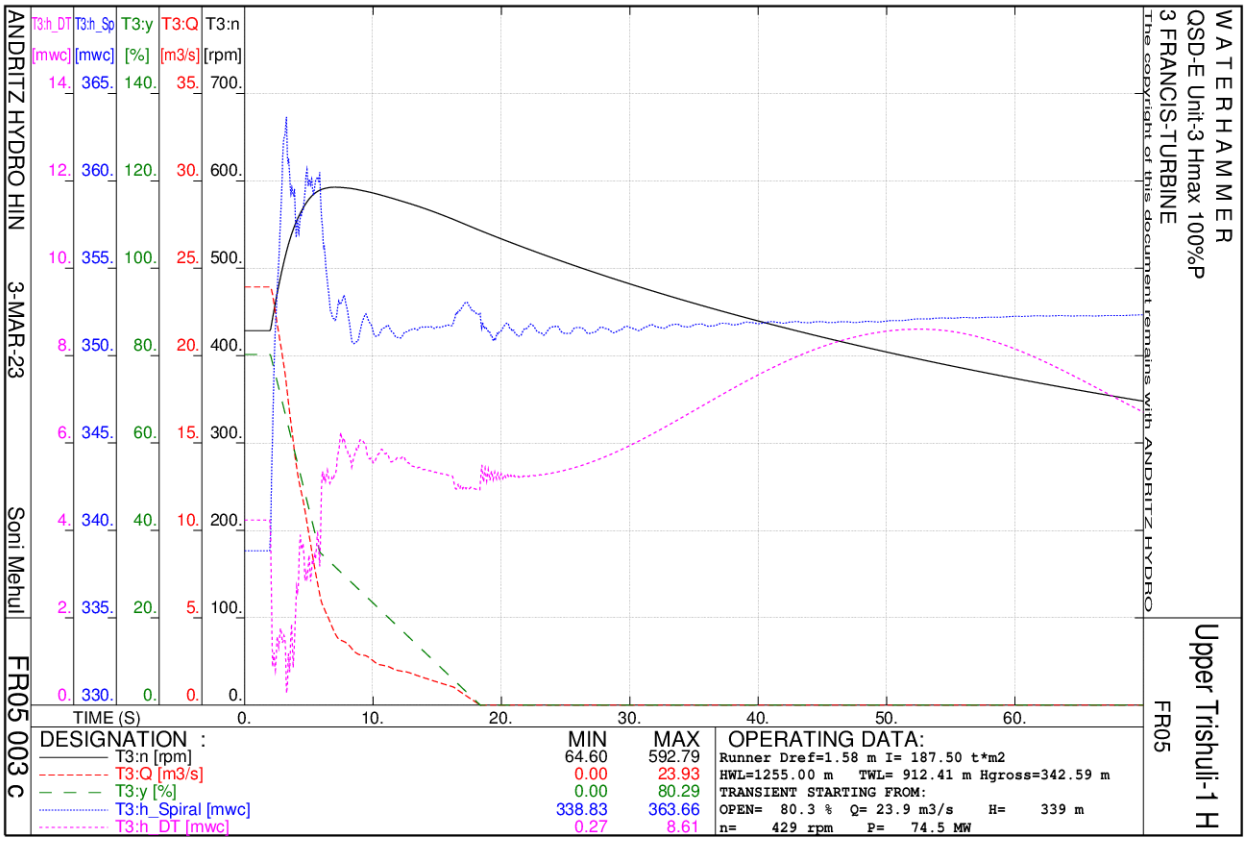
FR05 002 d
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1247.70 MAX 1259.00
DTSSHAFT U1_level [masl] 910.64 914.02
DTSSHAFT U2_level [masl] 910.64 914.02
DTSSHAFT U3_level [masl] 910.64 914.02
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW



FR05 002 QSD-E Unit-1 Hmax 100%P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QSD-E Unit-3 Hmax 100%P
3 FRANCIS-TURBINE
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FR05 003 c
Upper Trishuli-1 H
FR05
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm] MIN 64.60 MAX 592.79
T3:Q [m3/s] MIN 0.00 MAX 23.93
T3:y [%] MIN 0.00 MAX 80.29
T3:h_Spiral [mwc] MIN 338.83 MAX 363.66
T3:h_DT [mwc] MIN 0.27 MAX 8.61
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
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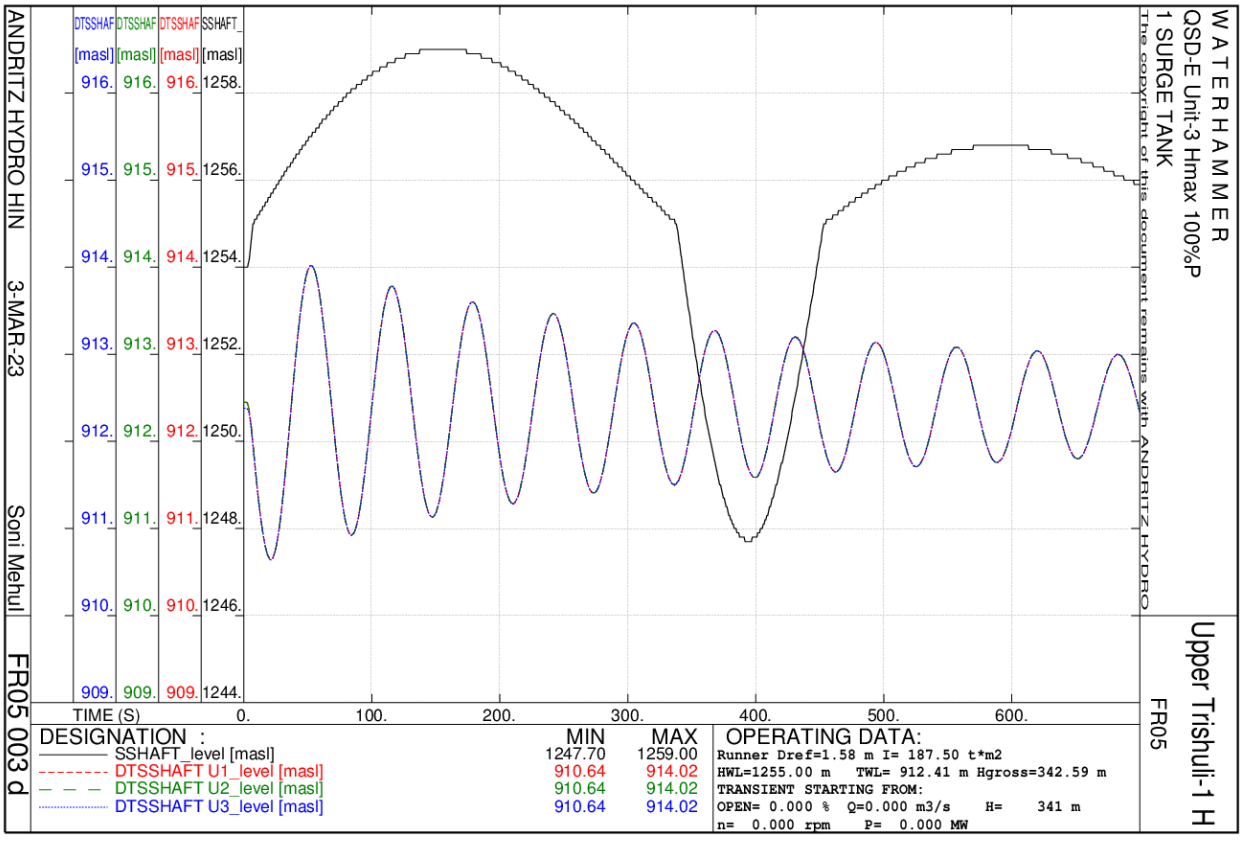
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E Unit-3 Hmax 100%P
1 SURGE TANK
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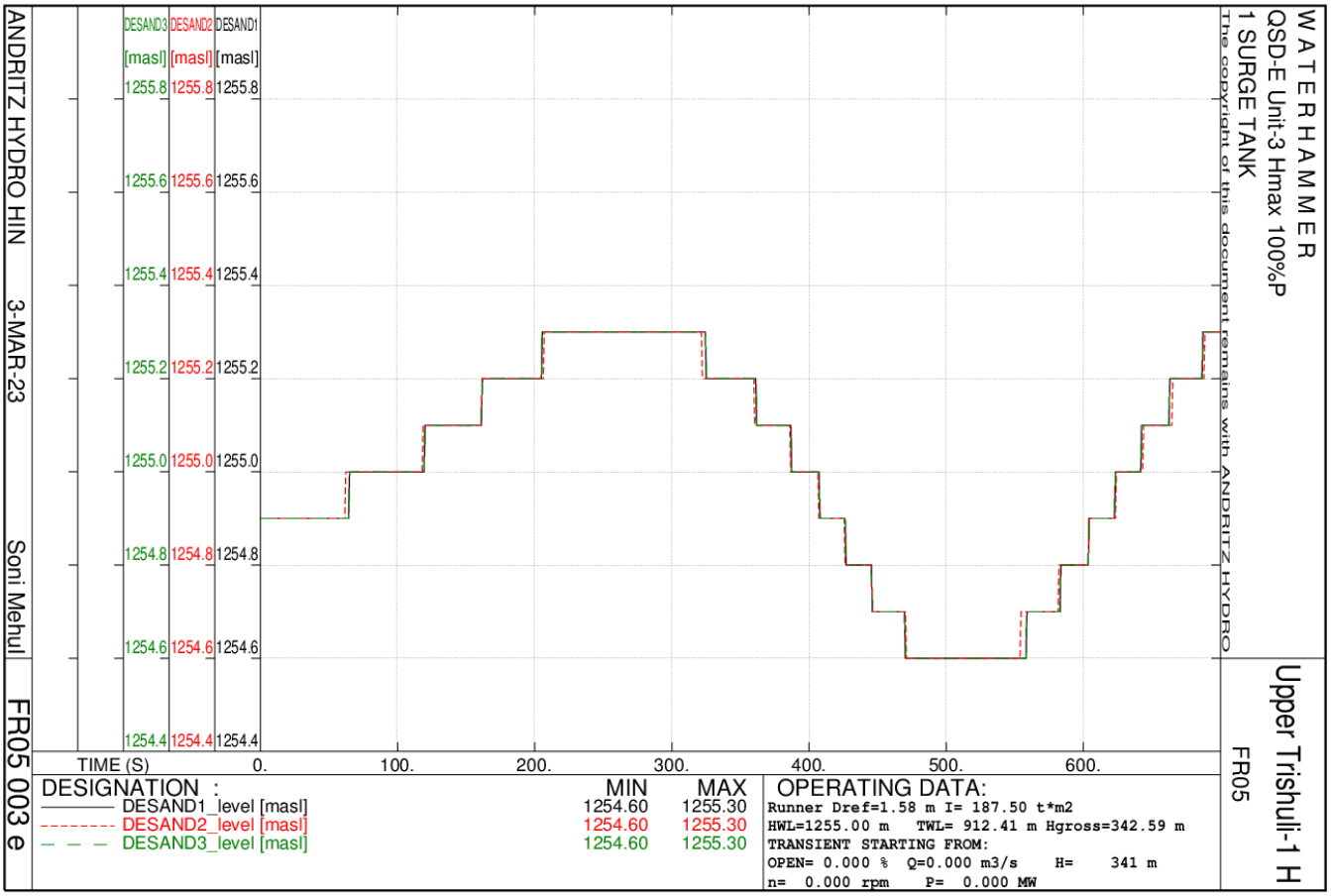
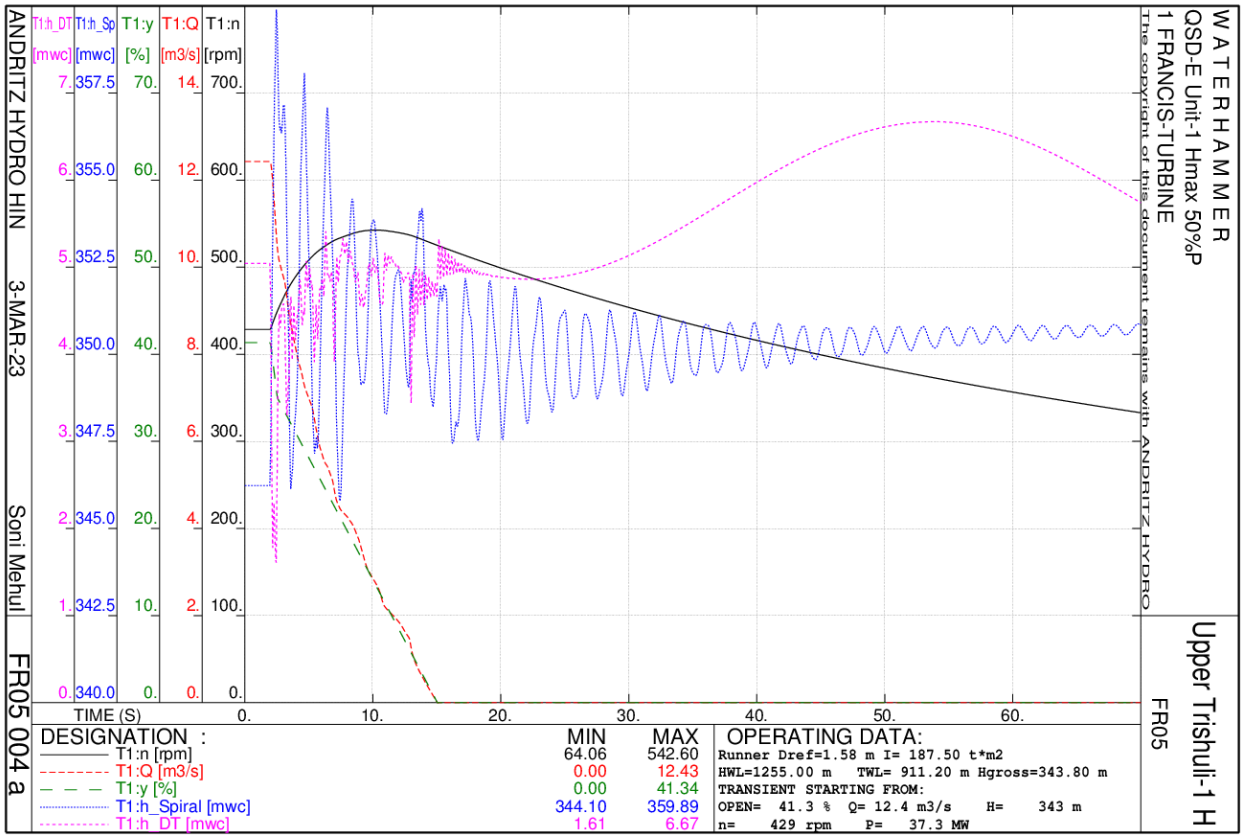
FR05
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1247.70 MAX 1259.00
DTSSHAFT U1_level [masl] MIN 910.64 MAX 914.02
DTSSHAFT U2_level [masl] MIN 910.64 MAX 914.02
DTSSHAFT U3_level [masl] MIN 910.64 MAX 914.02
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 0.000 % Q=0.000 m3/s H= 341 m
n= 0.000 rpm P= 0.000 MW



FR05 003 QSD-E Unit-3 Hmax 100%


WATERHAMMER
QSD-E Unit-1 Hmax 50%P
1 FRANCIS-TURBINE
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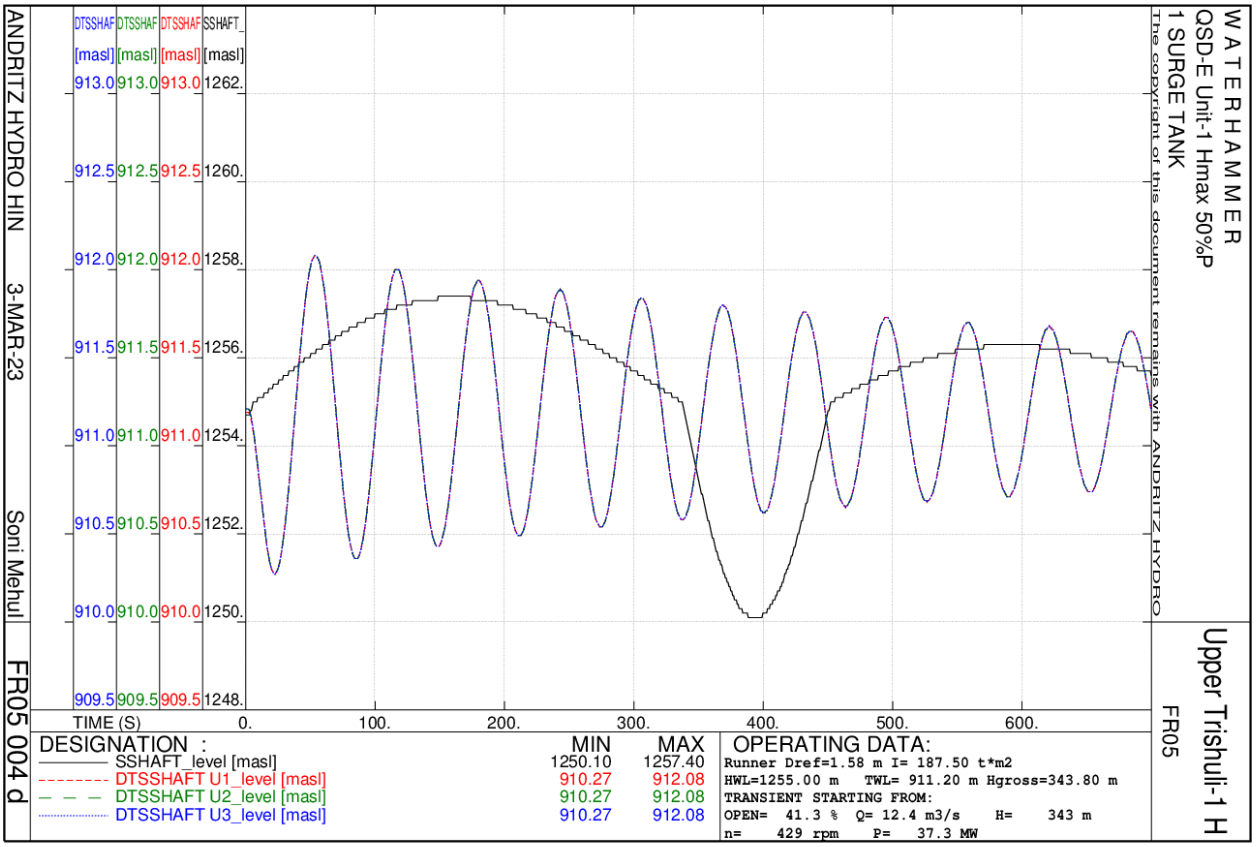
Soni Mehul
FR05 004 a
Upper Trishuli-1 H
FR05
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 64.06 MAX 542.60
T1:Q [m3/s] MIN 0.00 MAX 12.43
T1:y [%] MIN 0.00 MAX 41.34
T1:h_Spiral [mwc] MIN 344.10 MAX 359.89
T1:h_DT [mwc] MIN 1.61 MAX 6.67
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 911.20 m Hgross=343.80 m
TRANSIENT STARTING FROM:
OPEN= 41.3 % Q= 12.4 m3/s H= 343 m
n= 429 rpm P= 37.3 MW


WATERHAMMER
QSD-E Unit-1 Hmax 50%P
1 SURGE TANK
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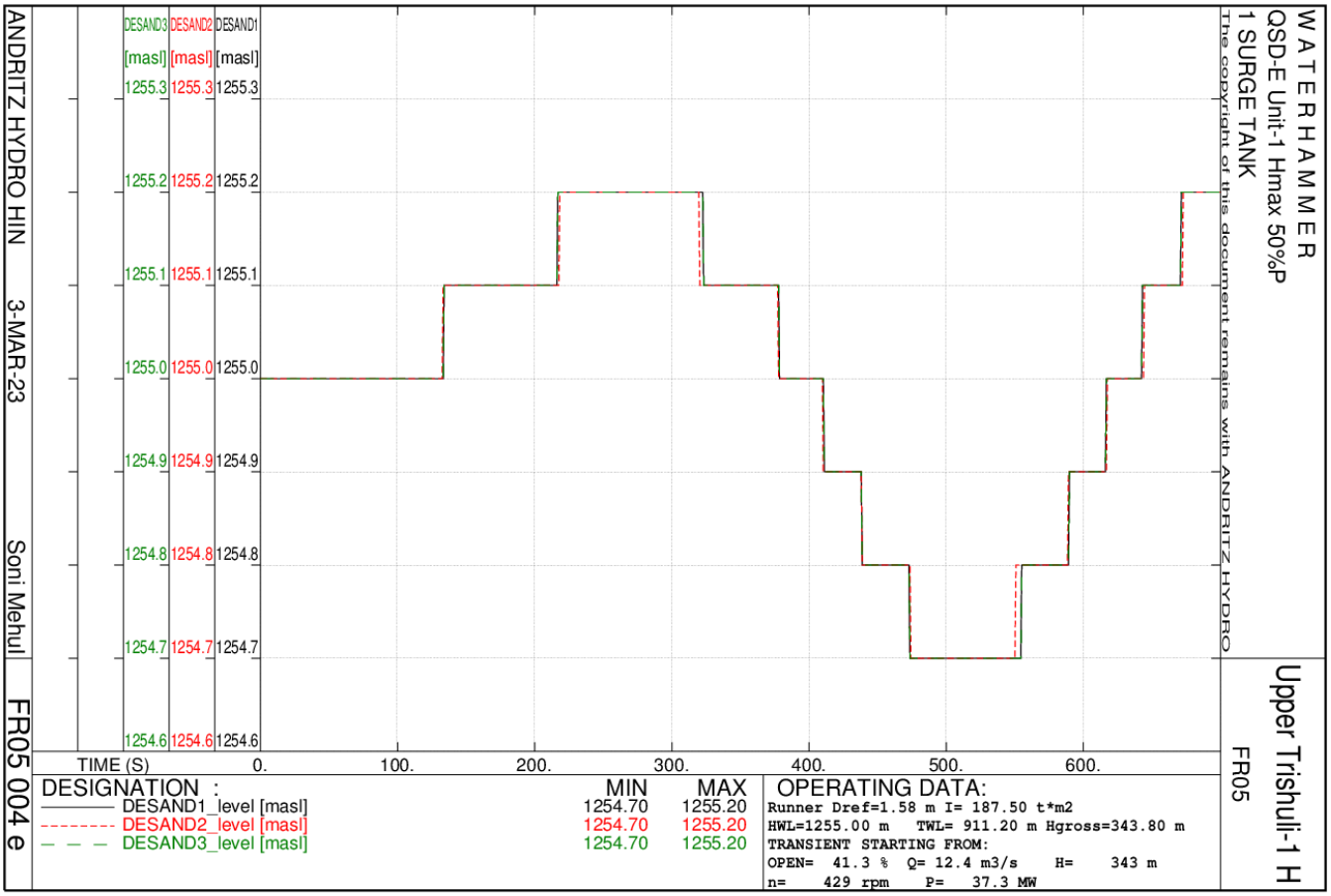
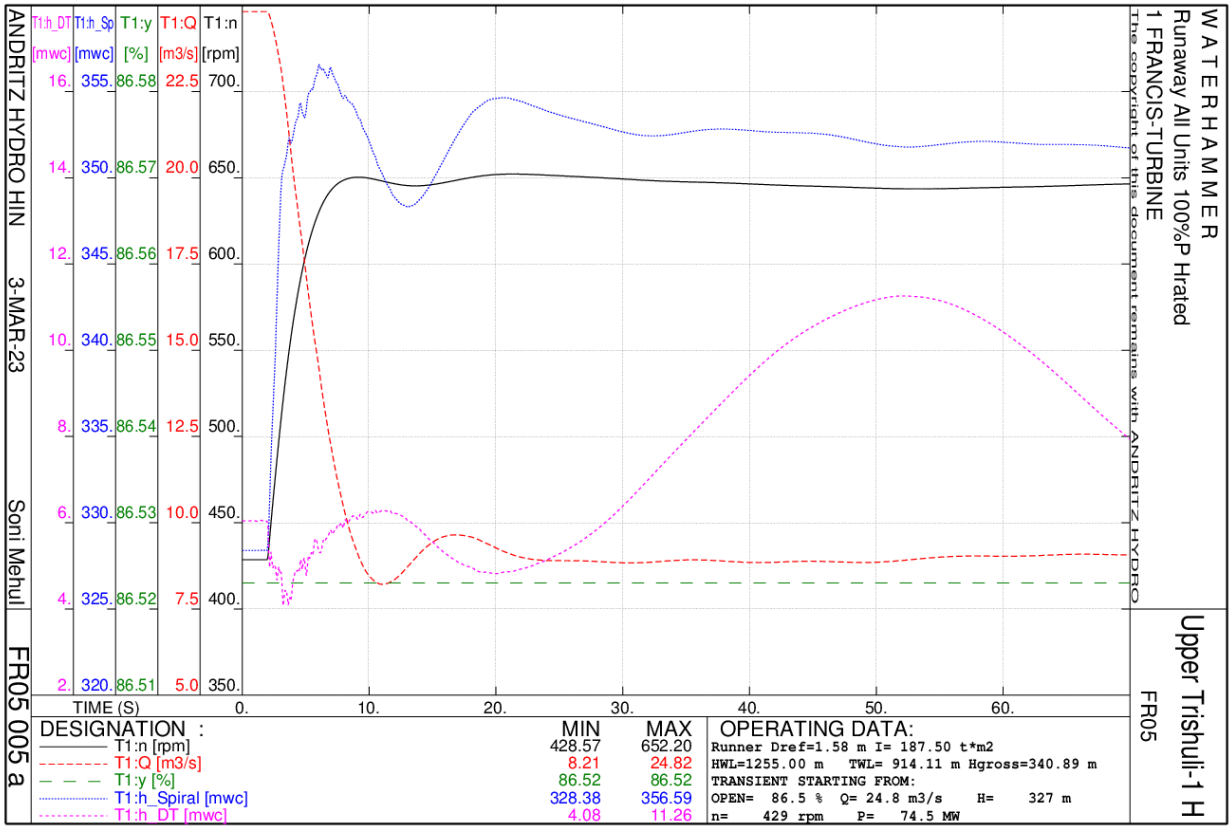
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 004 d
Upper Trishuli-1 H
FR05
DTSSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1250.10 MAX 1257.40
DTSSHAFT U1_level [masl] MIN 910.27 MAX 912.08
DTSSHAFT U2_level [masl] MIN 910.27 MAX 912.08
DTSSHAFT U3_level [masl] MIN 910.27 MAX 912.08
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 911.20 m Hgross=343.80 m
TRANSIENT STARTING FROM:
OPEN= 41.3 % Q= 12.4 m3/s H= 343 m
n= 429 rpm P= 37.3 MW



FR05 004 QSD-E Unit-1 Hmax 50%P


WATERHAMMER
Runaway All Units 100%P Hrated
1 FRANCIS-TURBINE
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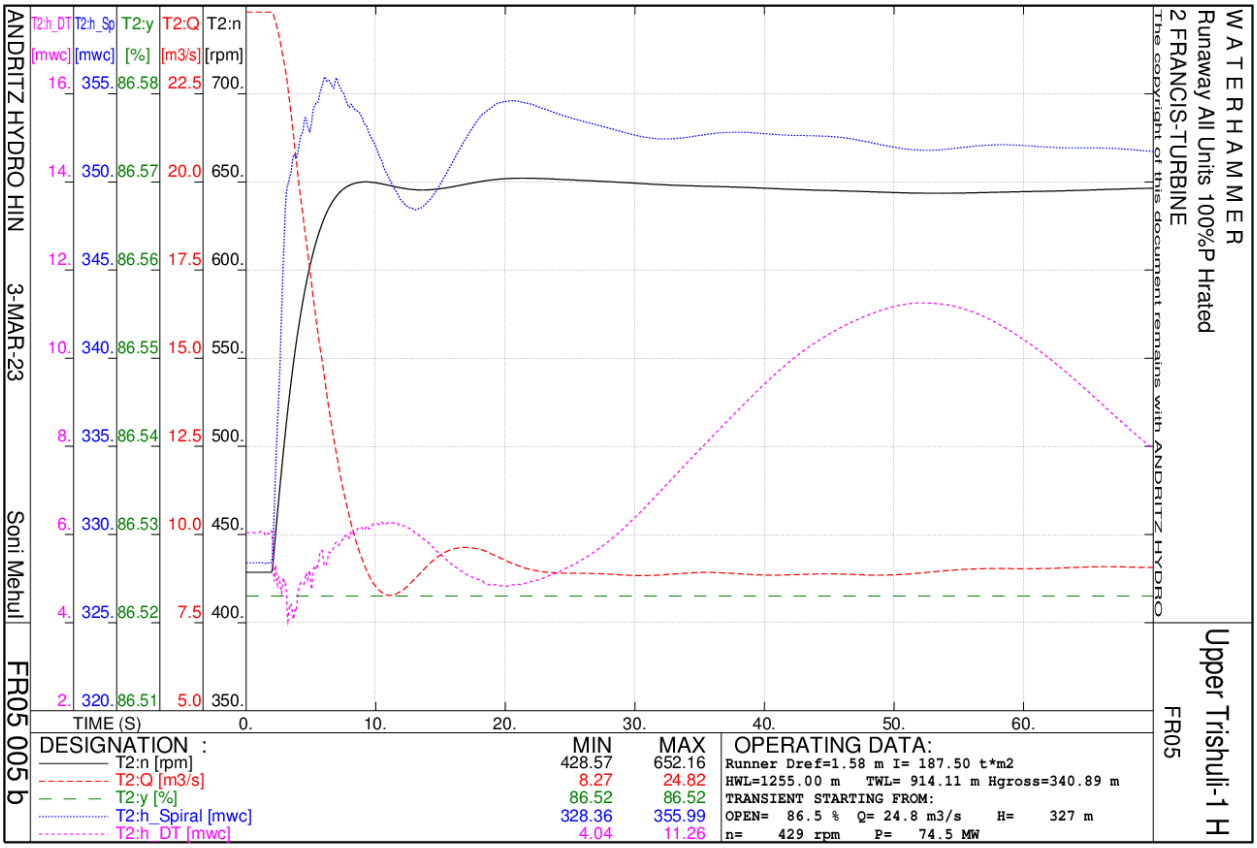
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 005 a
Upper Trishuli-1 H
FR05
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
T1:h_Spiral [mwc]
T1:h_DT [mwc]
MIN
428.57
8.21
86.52
328.38
4.08
MAX
652.20
24.82
86.52
356.59
11.26
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway All Units 100%P Hrated
2 FRANCIS-TURBINE
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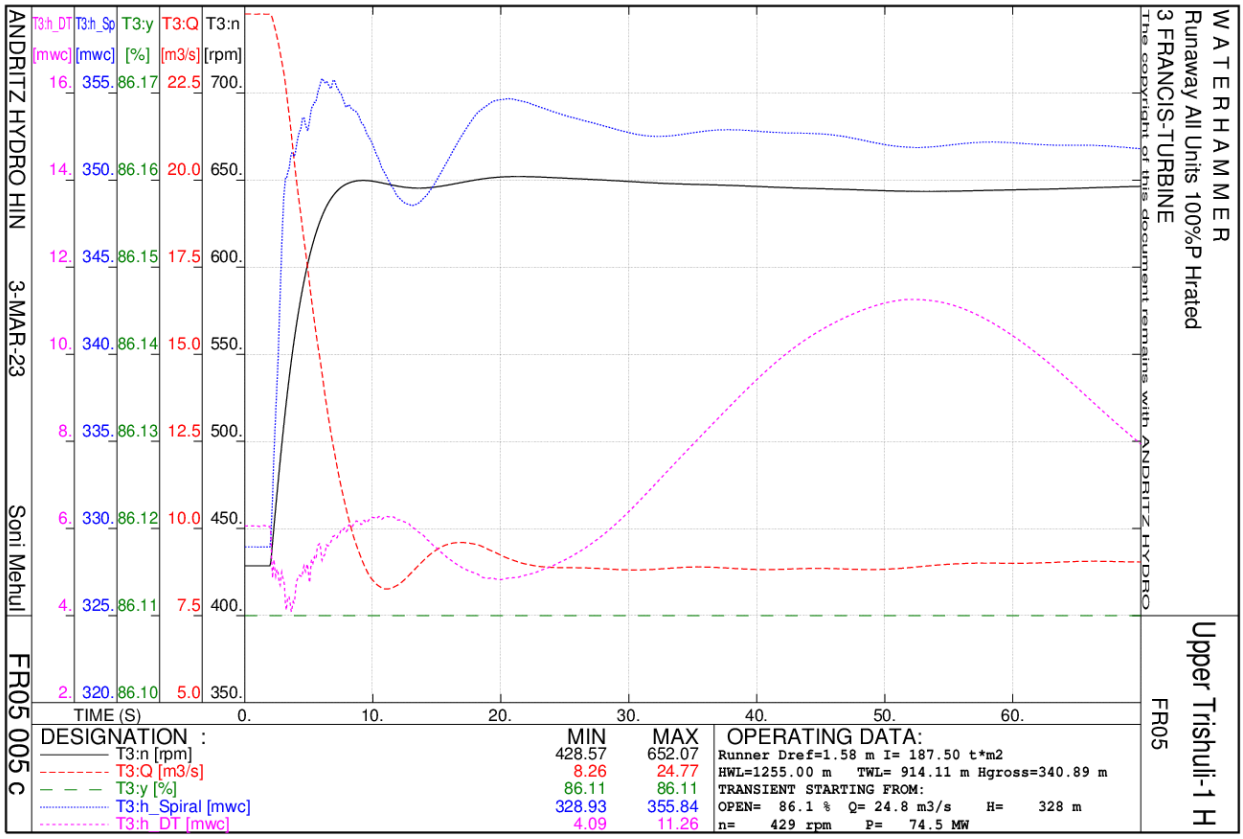
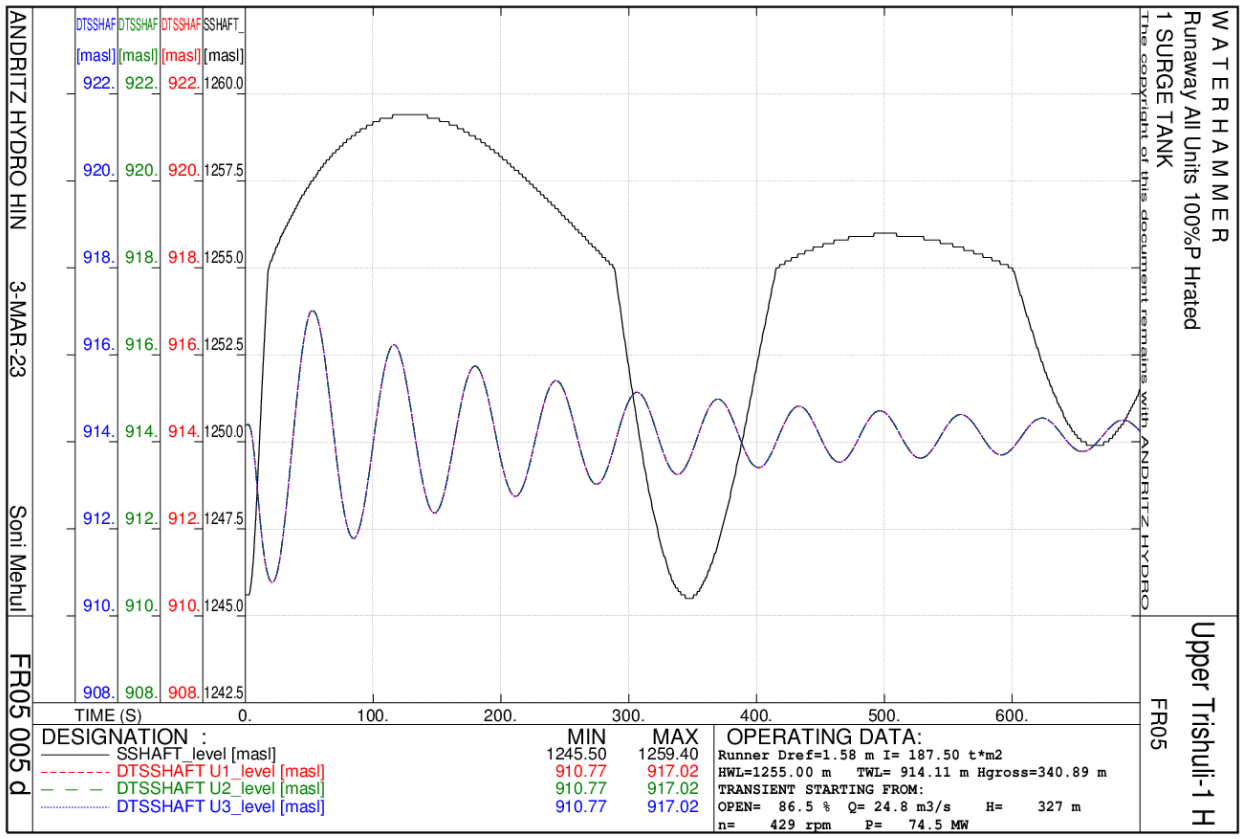
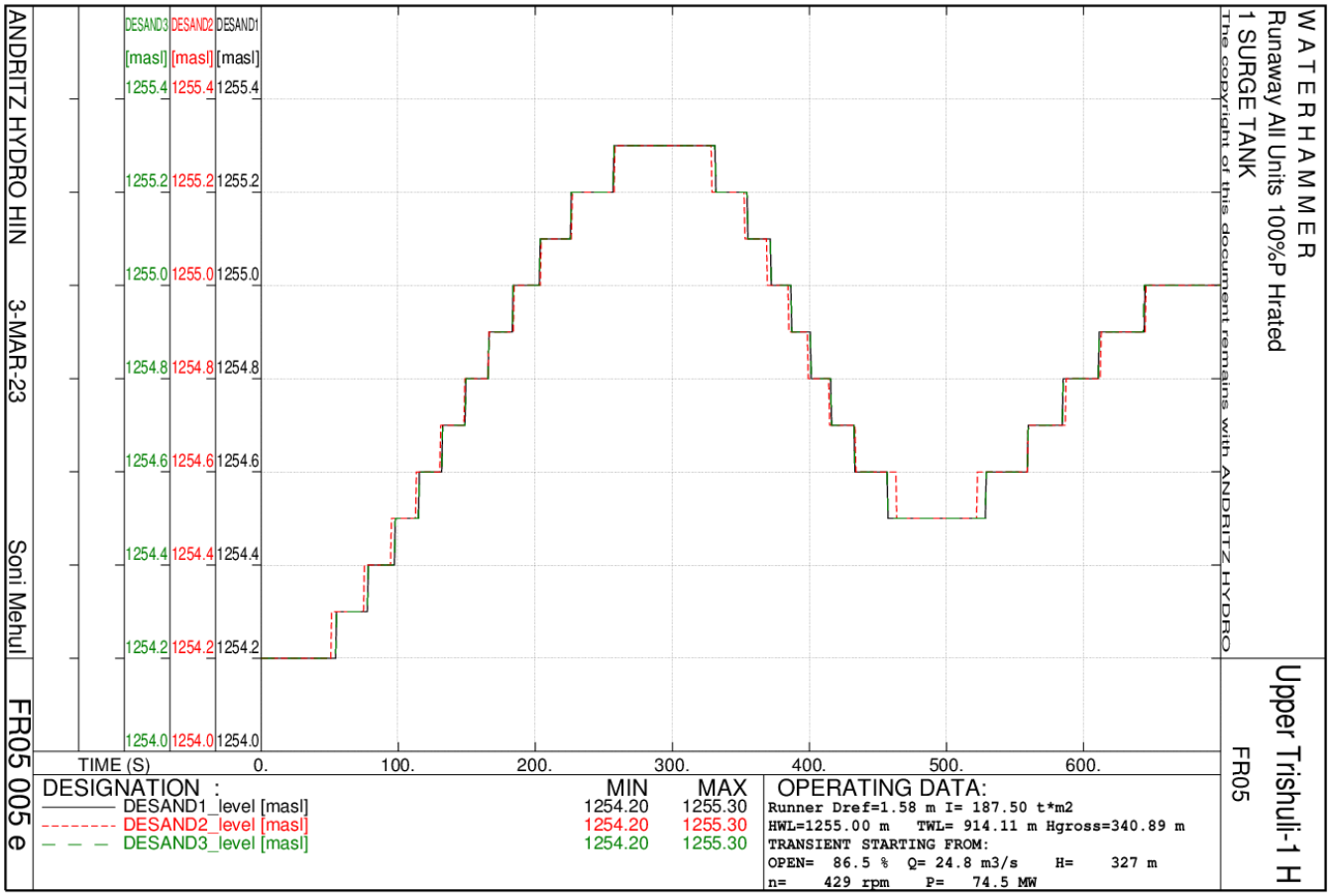
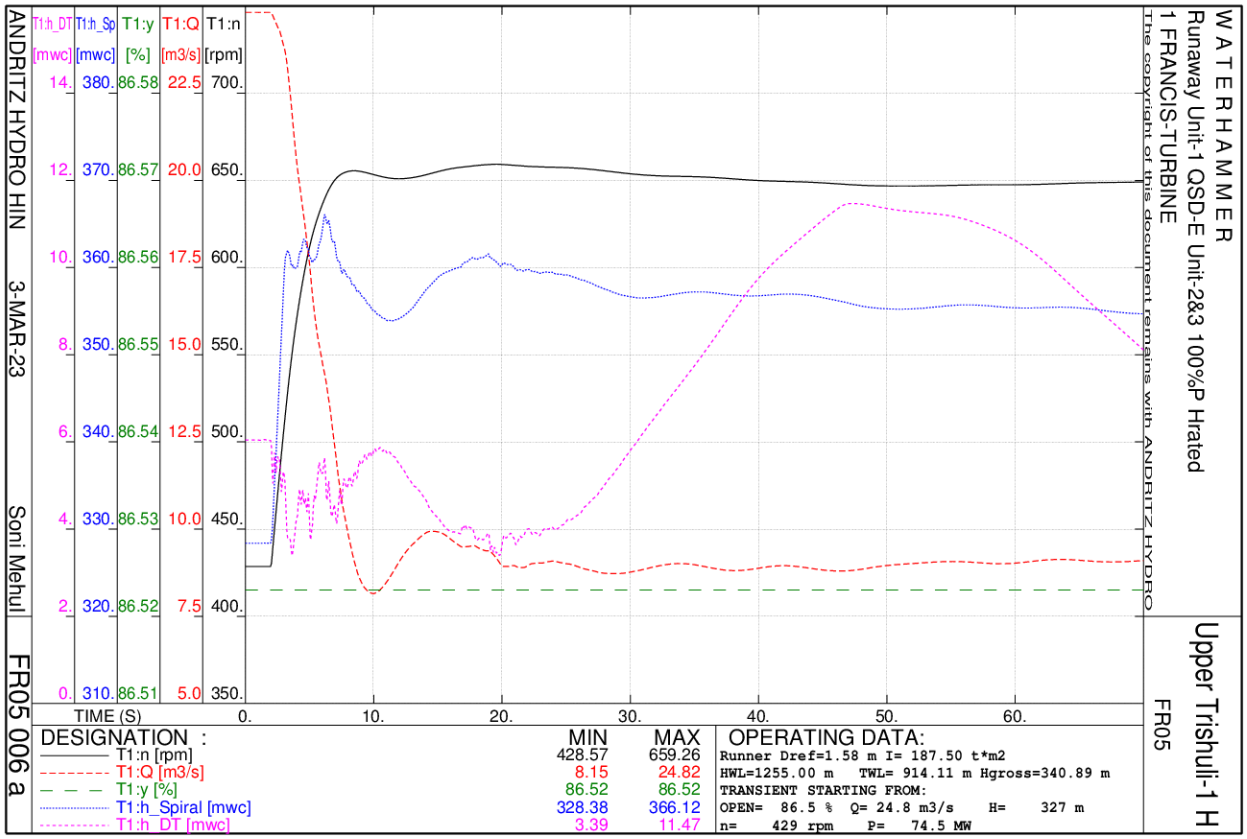
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 005 b
Upper Trishuli-1 H
FR05
T2:h_DT [mwc]
T2:h_Sp [mwc]
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
TIME (S)
DESIGNATION :
T2:n [rpm]
T2:Q [m3/s]
T2:y [%]
T2:h_Spiral [mwc]
T2:h_DT [mwc]
MIN
428.57
8.27
86.52
328.36
4.04
MAX
652.16
24.82
86.52
355.99
11.26
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW

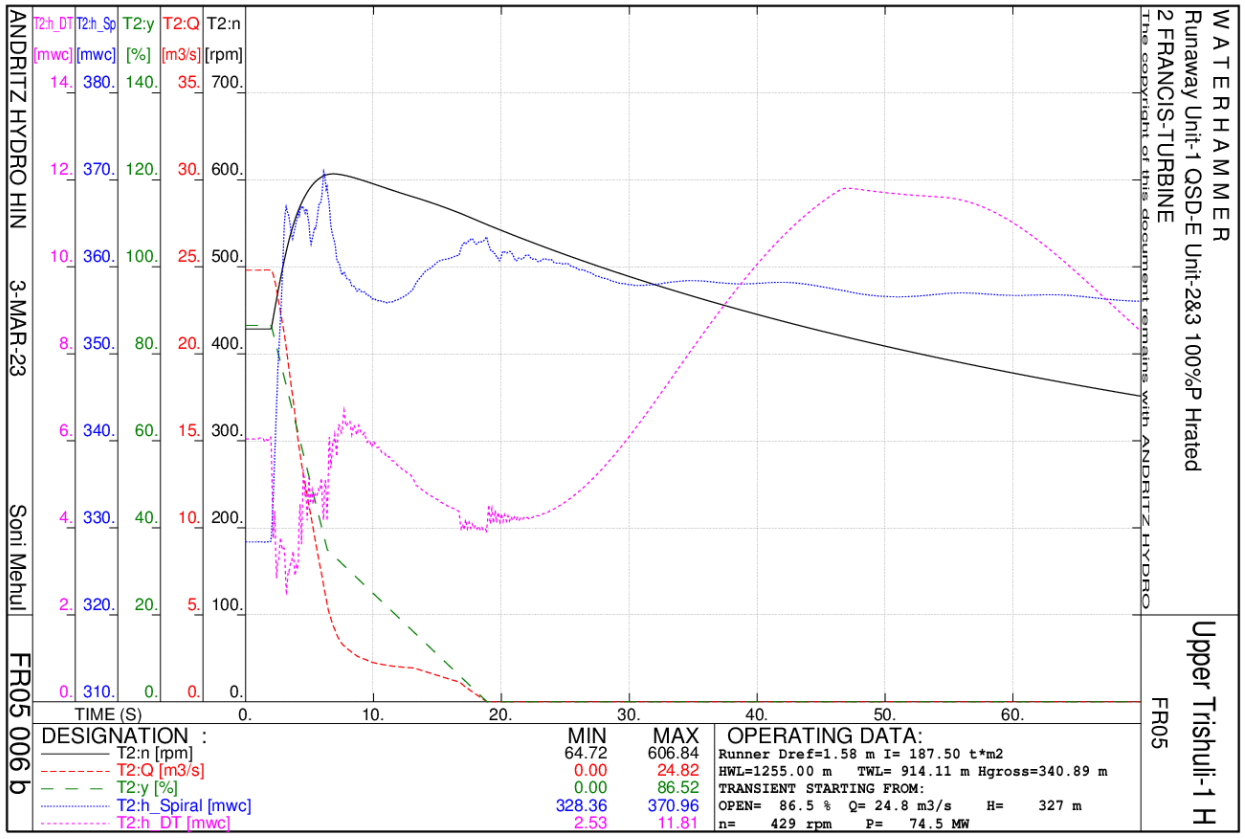

WATERHAMMER
Runaway All Units 100%P Hrated
3 FRANCIS-TURBINE
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 005 c
Upper Trishuli-1 H
FR05
TIME (S)
DESIGNATION :
T3:n [rpm]
T3:Q [m3/s]
T3:y [%]
T3:h_Spiral [mwc]
T3:h_DT [mwc]
MIN
MAX
428.57 652.07
8.26 24.77
86.11 86.11
328.93 355.84
4.09 11.26
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.1 % Q= 24.8 m3/s H= 328 m
n= 429 rpm P= 74.5 MW

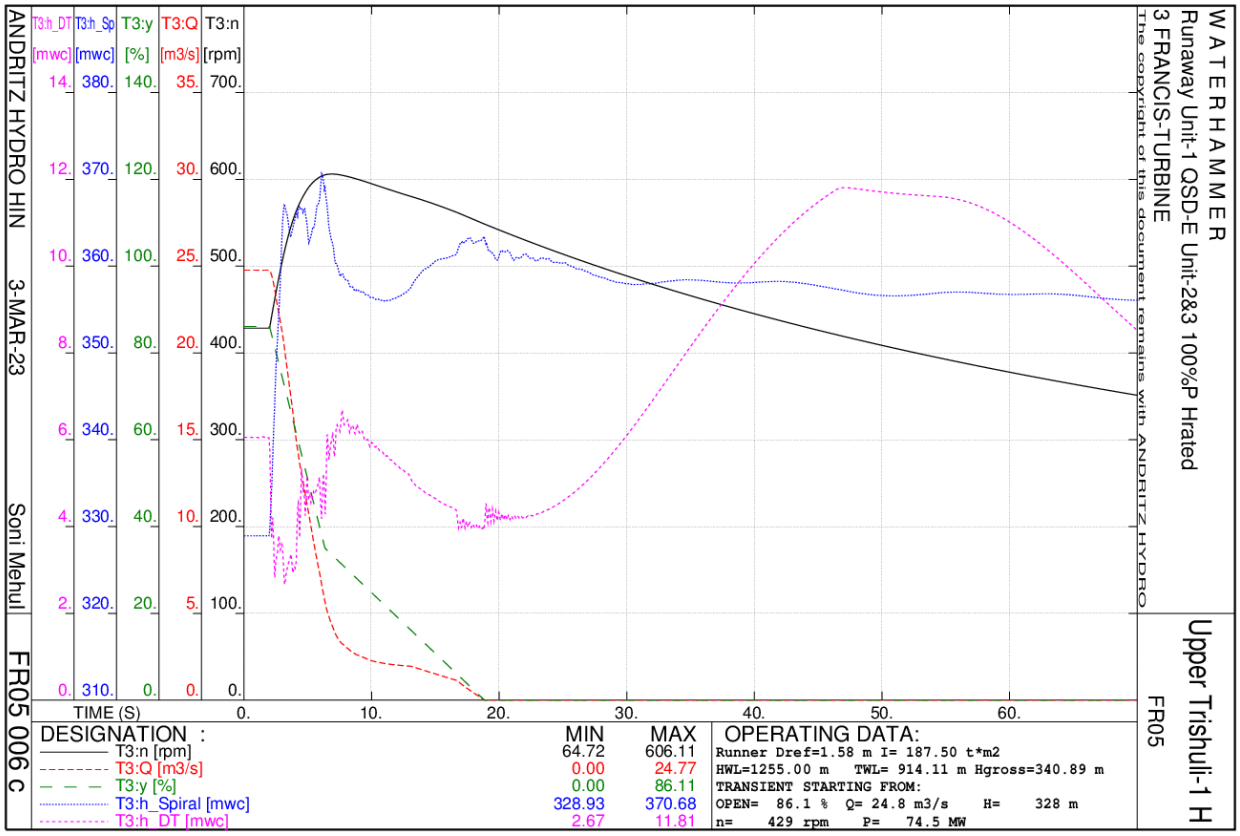

WATERHAMMER
Runaway All Units 100%P Hrated
1 SURGE TANK
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 005 d
Upper Trishuli-1 H
FR05
TIME (S)
DESIGNATION :
SSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
MIN
MAX
1245.50 1259.40
910.77 917.02
910.77 917.02
910.77 917.02
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



FR05 005 Runaway All Units 100%P Hrated


WATERHAMMER
Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated
1 FRANCIS-TURBINE
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 006 a
Upper Trishuli-1 H
FR05
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 428.57 MAX 659.26
T1:Q [m3/s] 8.15 24.82
T1:y [%] 86.52 86.52
T1:h_Spiral [mwc] 328.38 366.12
T1:h_DT [mwc] 3.39 11.47
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated
2 FRANCIS-TURBINE
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 006 b
Upper Trishuli-1 H
FR05
T2:h_DT [mwc]
T2:h_Sp [mwc]
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
TIME (S)
DESIGNATION :
T2:n [rpm] MIN 64.72 MAX 606.84
T2:Q [m3/s] 0.00 24.82
T2:y [%] 0.00 86.52
T2:h_Spiral [mwc] 328.36 370.96
T2:h_DT [mwc] 2.53 11.81
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated
3 FRANCIS-TURBINE
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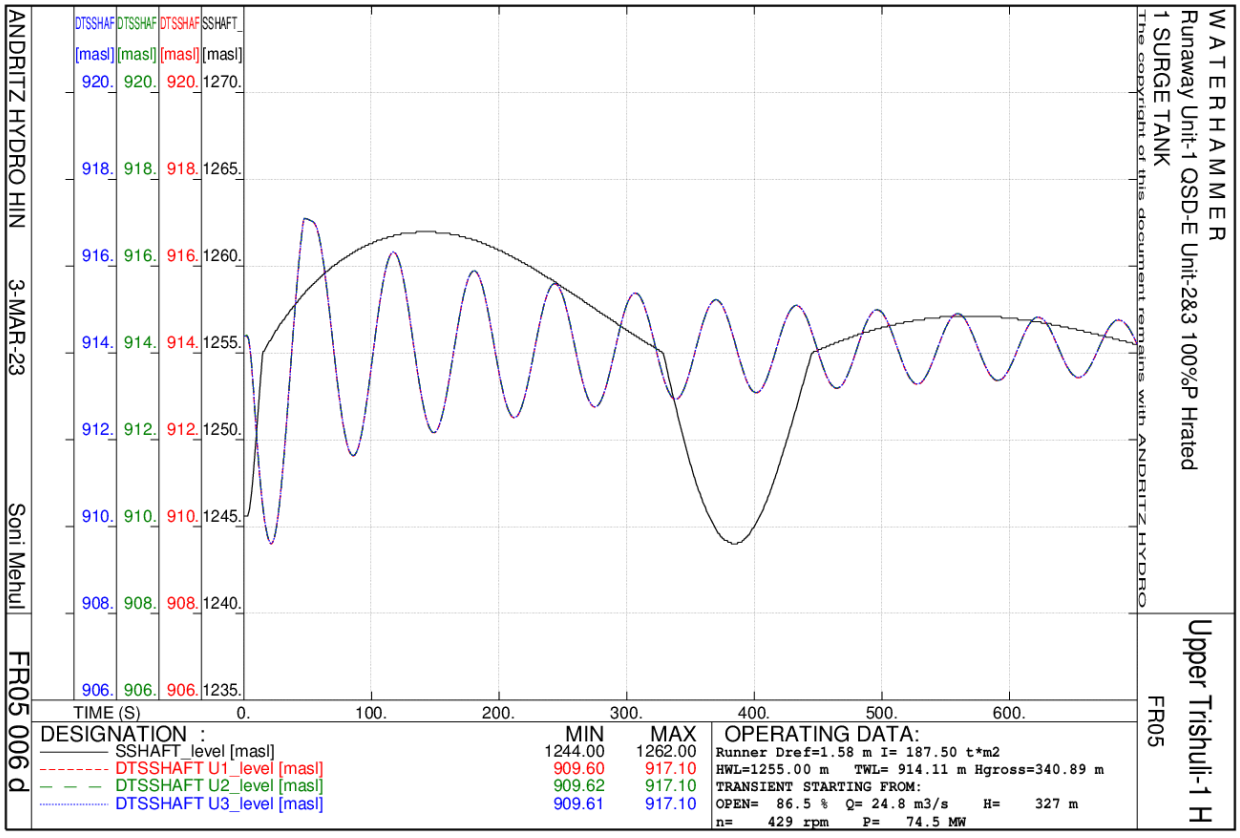
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 006 c
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION : MIN MAX
T3:n [rpm] 64.72 606.11
T3:Q [m3/s] 0.00 24.77
T3:y [%] 0.00 86.11
T3:h_Spiral [mwc] 328.93 370.68
T3:h_DT [mwc] 2.67 11.81
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.1 % Q= 24.8 m3/s H= 328 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated
1 SURGE TANK
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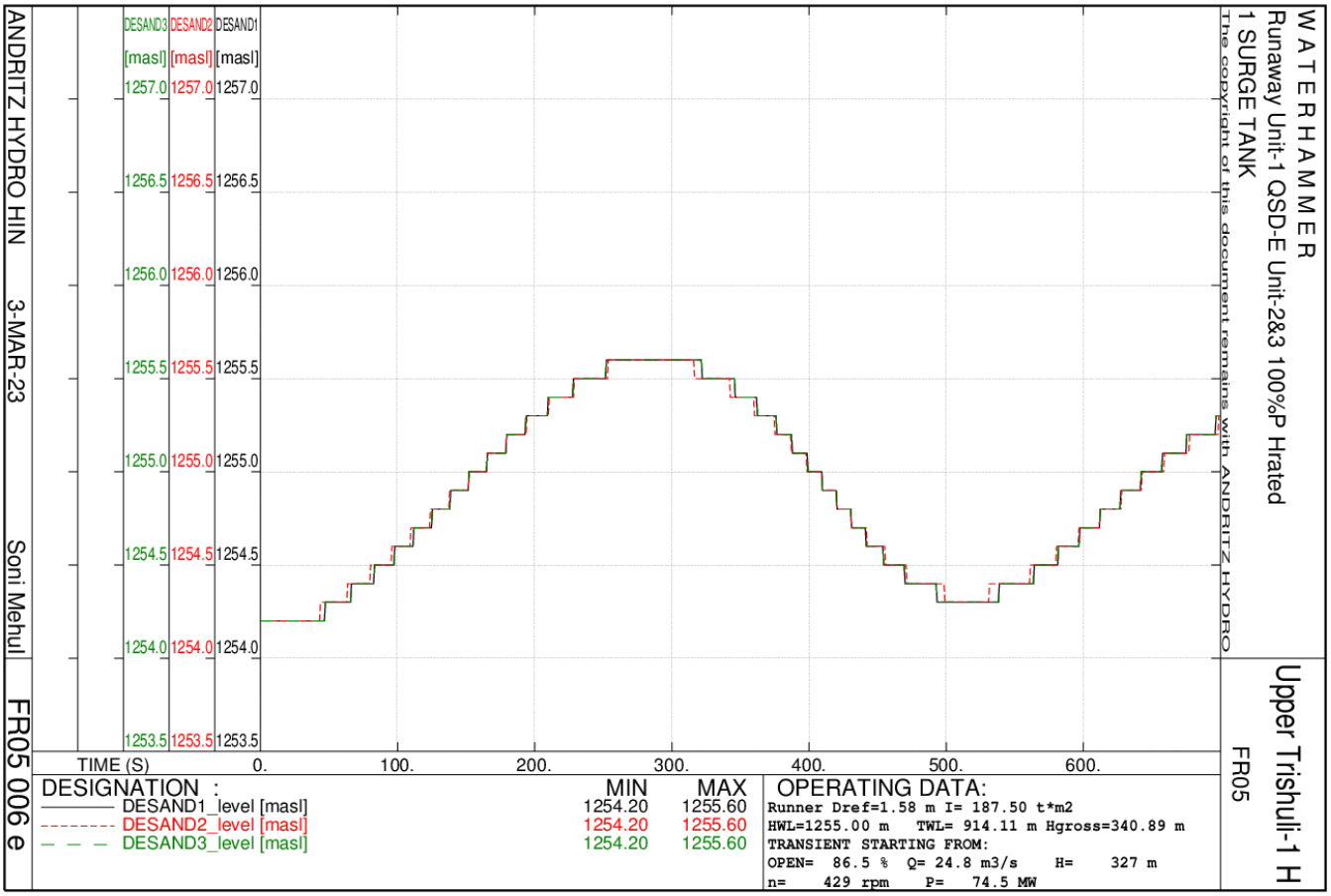
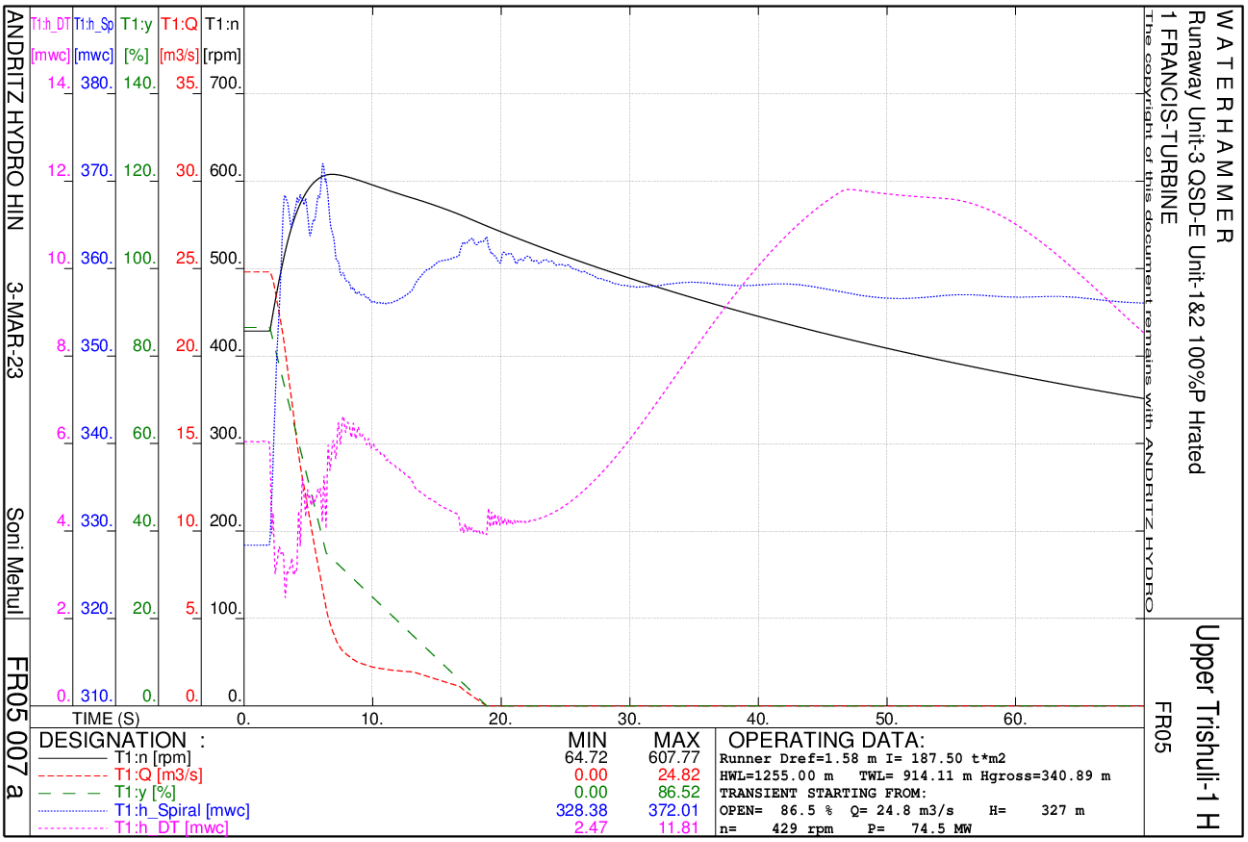
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 006 d
DTSSHAFT_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1244.00 1262.00
DTSSHAFT U1_level [masl] 909.60 917.10
DTSSHAFT U2_level [masl] 909.62 917.10
DTSSHAFT U3_level [masl] 909.61 917.10
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



FR05 006 Runaway Unit-1 QSD-E Unit-2&3 100%P Hrated


WATERHAMMER
Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated
1 FRANCIS-TURBINE
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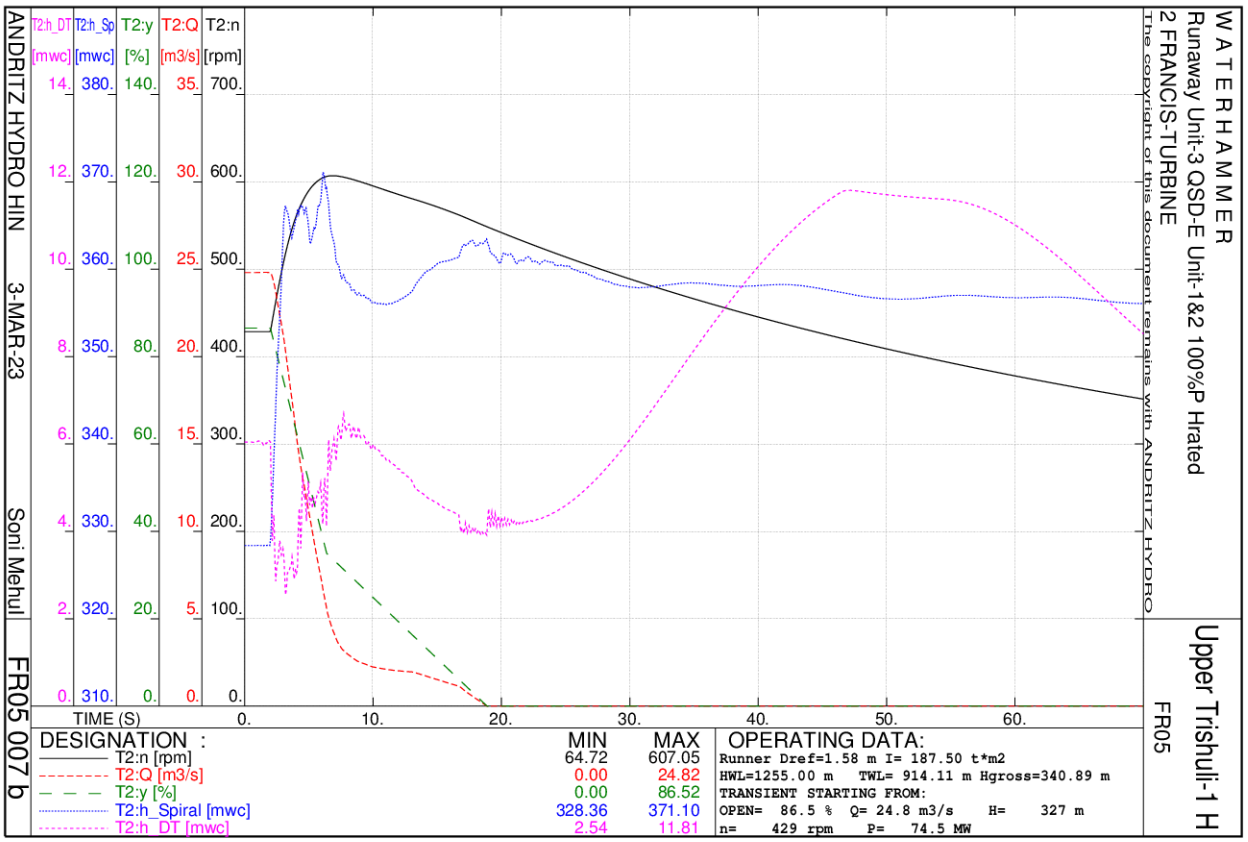
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 007 a
T1:h_DT [mwc] T1:h_Sp [mwc] T1:y [%] T1:Q [m3/s] T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 64.72 MAX 607.77
T1:Q [m3/s] 0.00 24.82
T1:y [%] 0.00 86.52
T1:h_Spiral [mwc] 328.38 372.01
T1:h_DT [mwc] 2.47 11.81
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated
2 FRANCIS-TURBINE
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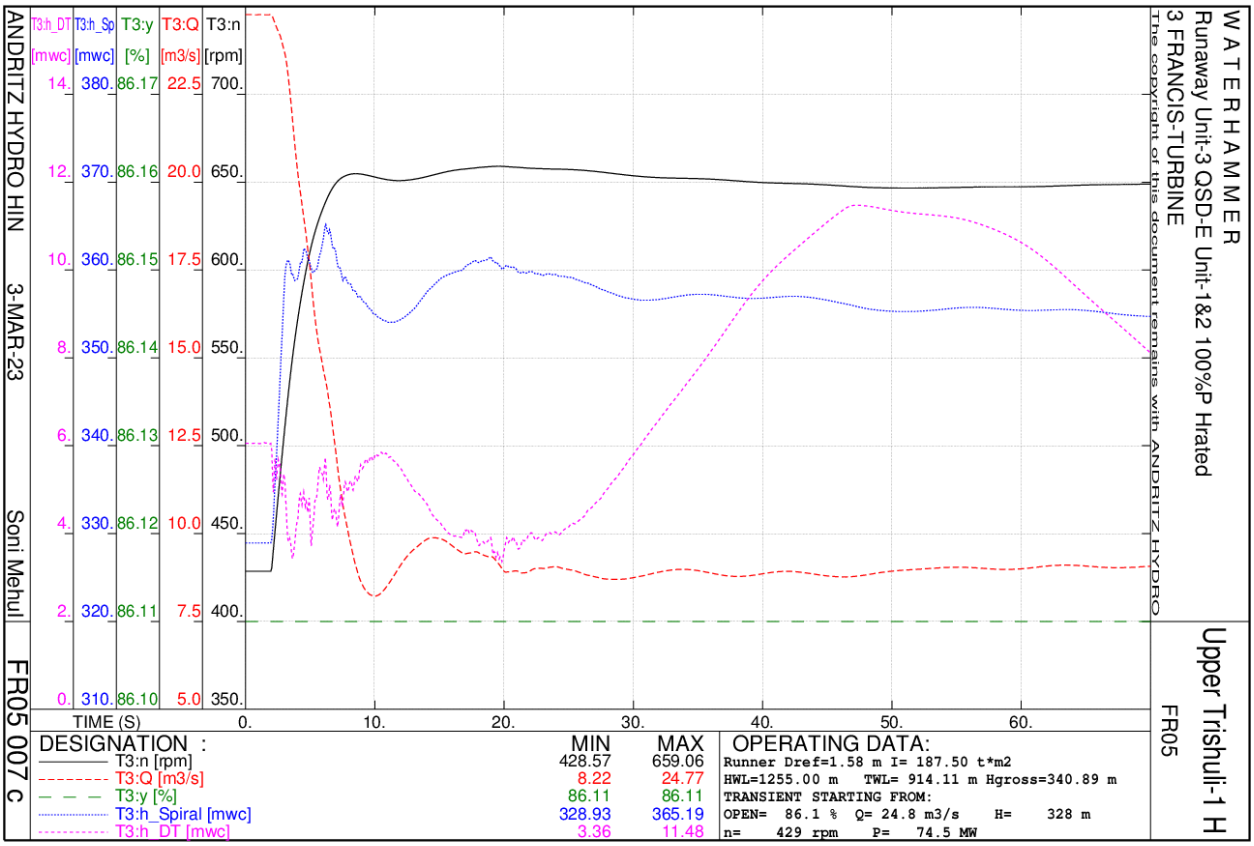
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 007 b
T2:h_DT [mwc] T2:h_Sp [mwc] T2:y [%] T2:Q [m3/s] T2:n [rpm]
TIME (S)
DESIGNATION :
T2:n [rpm] MIN 64.72 MAX 607.05
T2:Q [m3/s] 0.00 24.82
T2:y [%] 0.00 86.52
T2:h_Spiral [mwc] 328.36 371.10
T2:h_DT [mwc] 2.54 11.81
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated
3 FRANCIS-TURBINE
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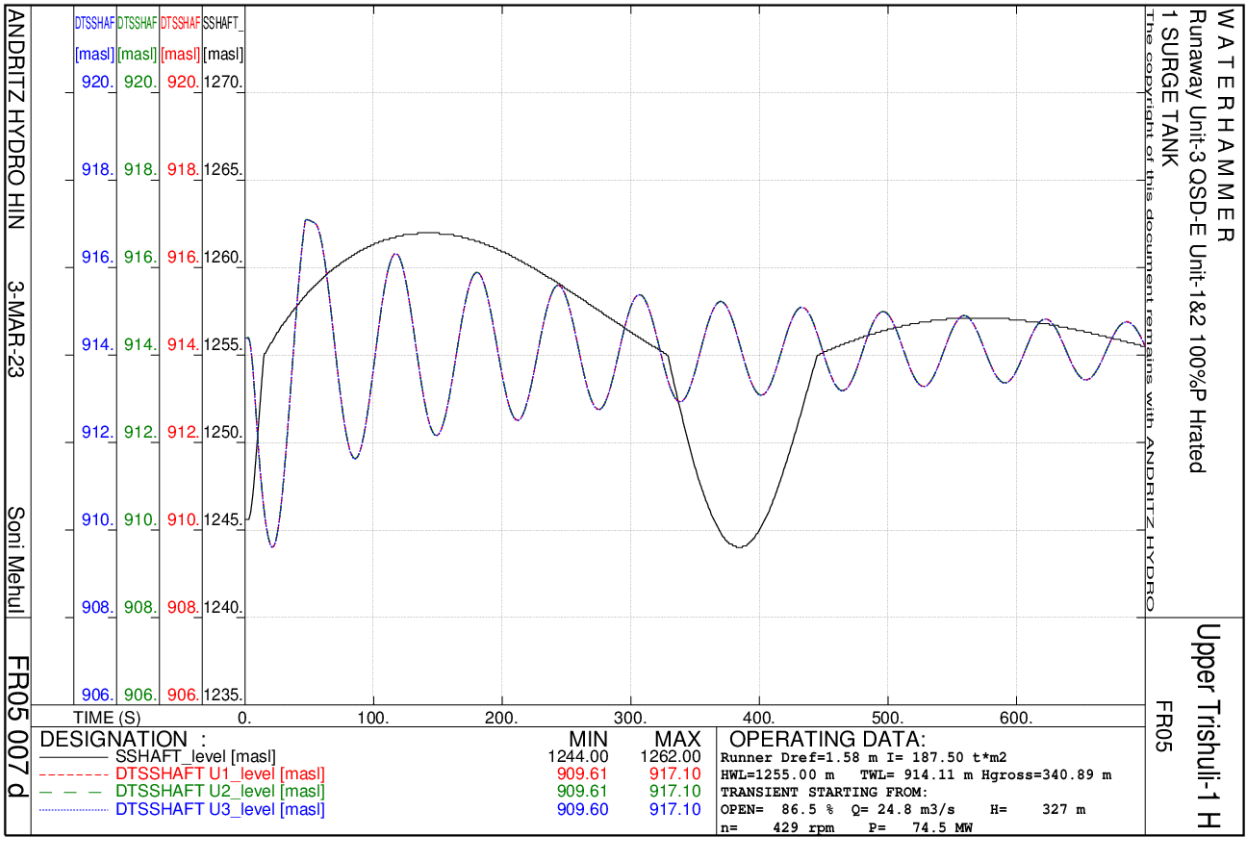
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 007 c
Upper Trishuli-1 H
FR05
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm]
T3:Q [m3/s]
T3:y [%]
T3:h_Spiral [mwc]
T3:h_DT [mwc]
MIN
428.57
8.22
86.11
328.93
3.36
MAX
659.06
24.77
86.11
365.19
11.48
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.1 % Q= 24.8 m3/s H= 328 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated
1 SURGE TANK
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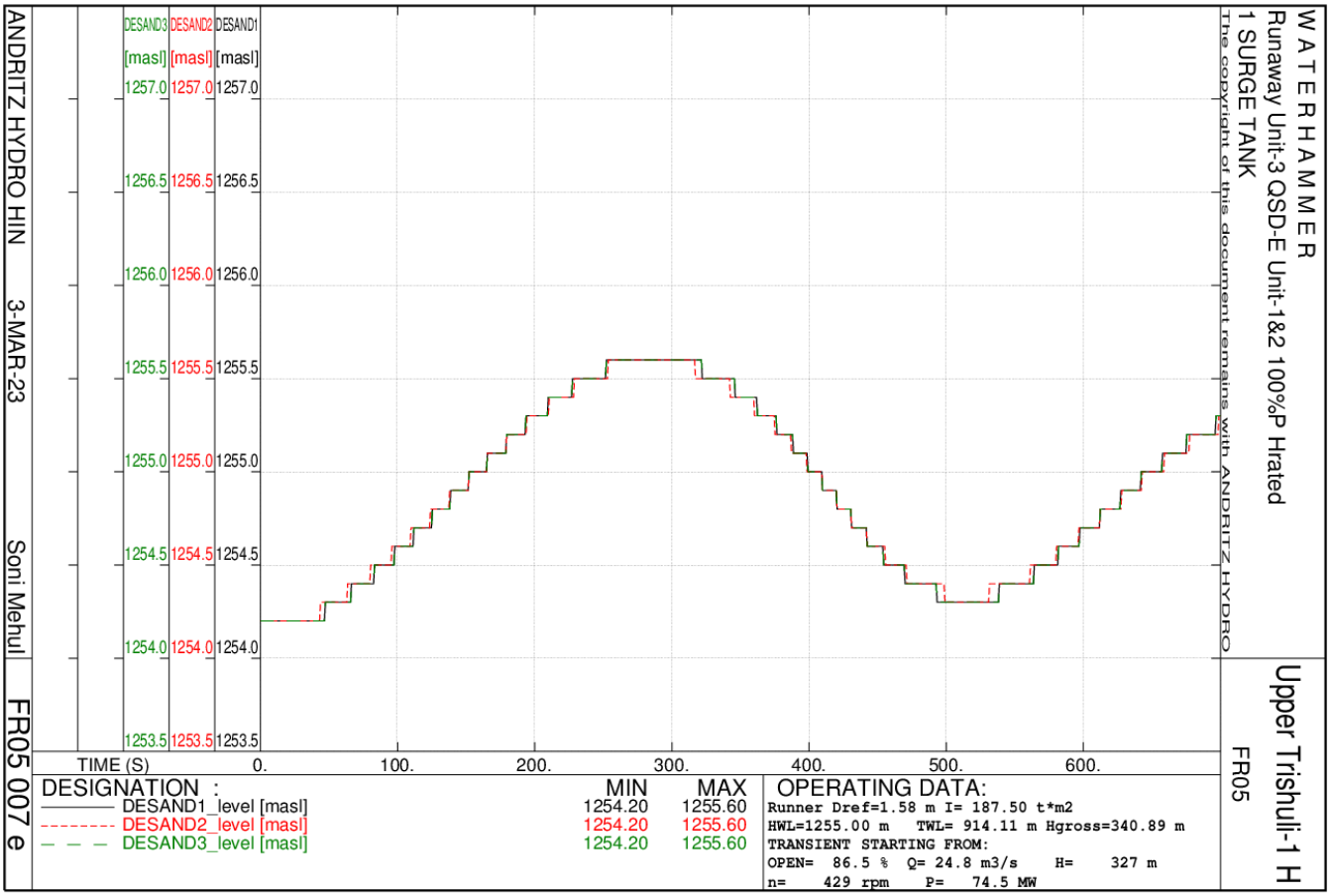
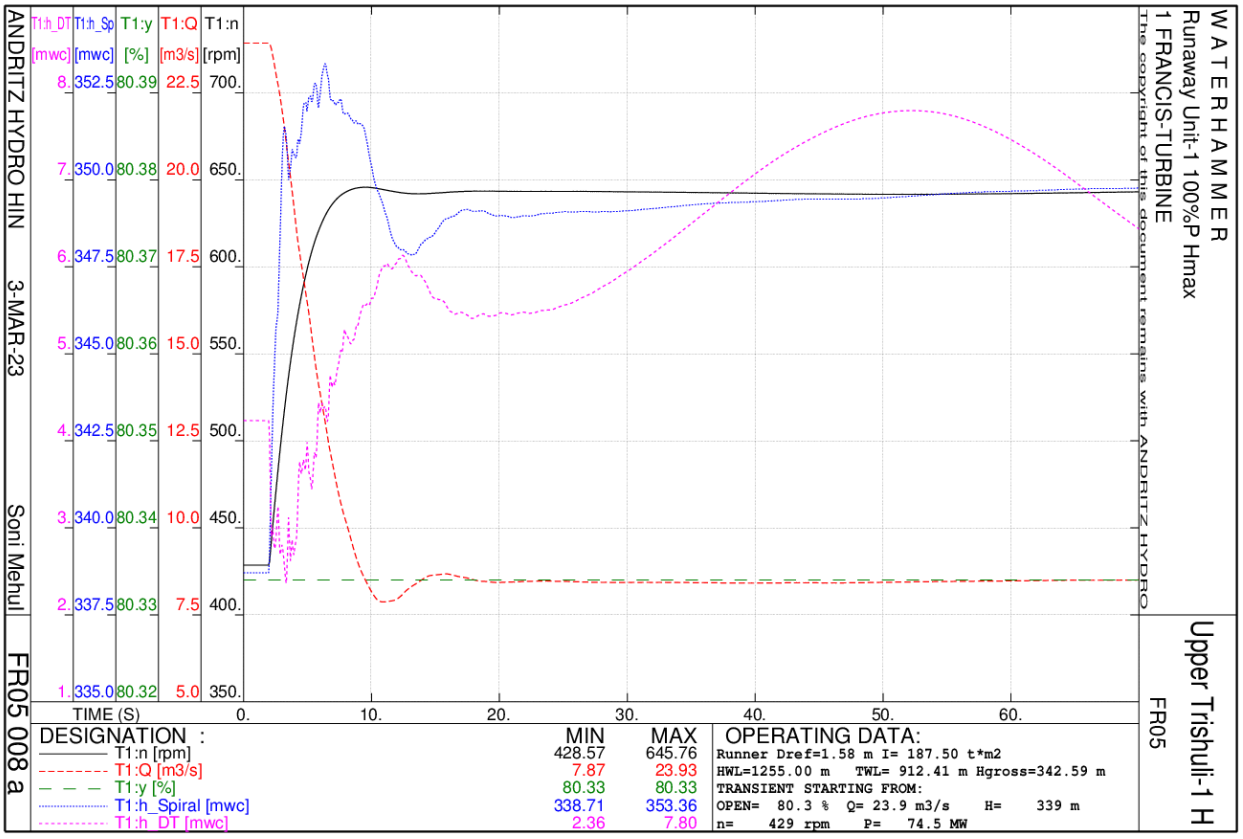
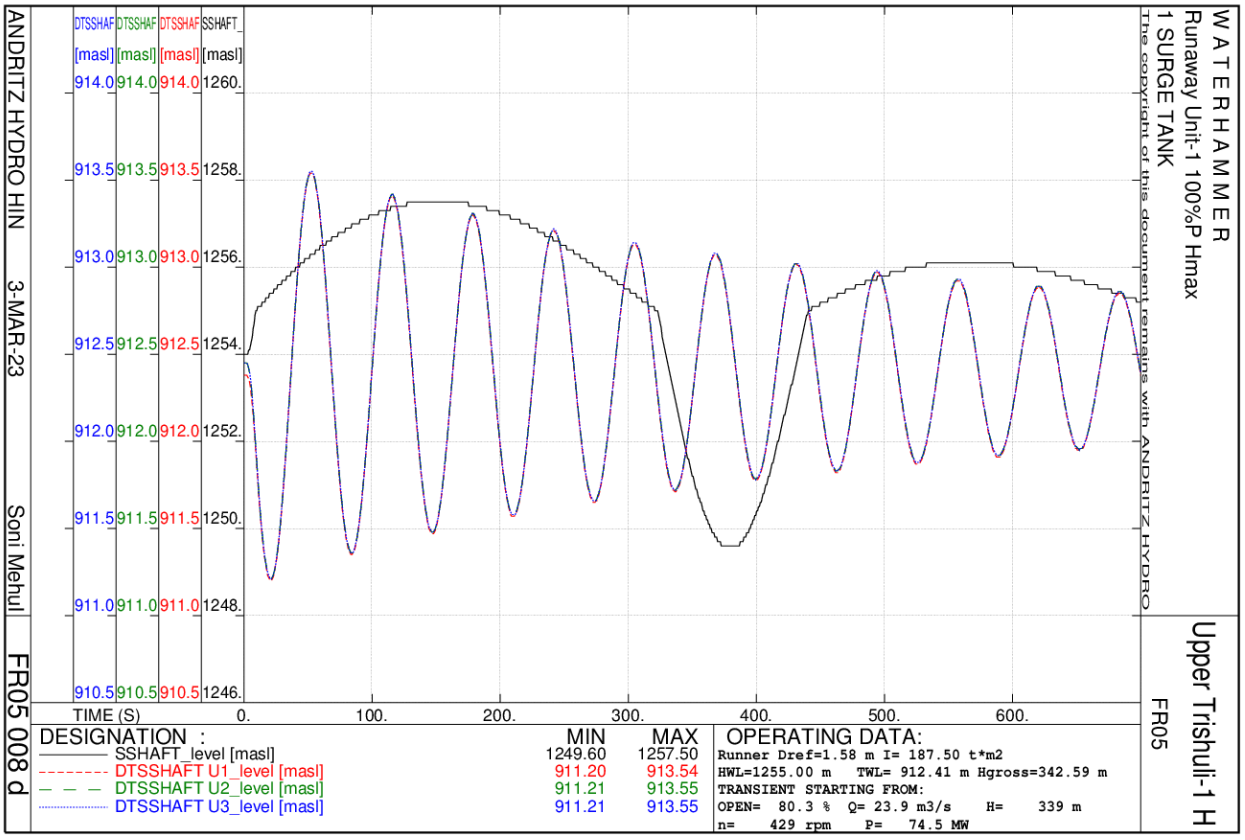
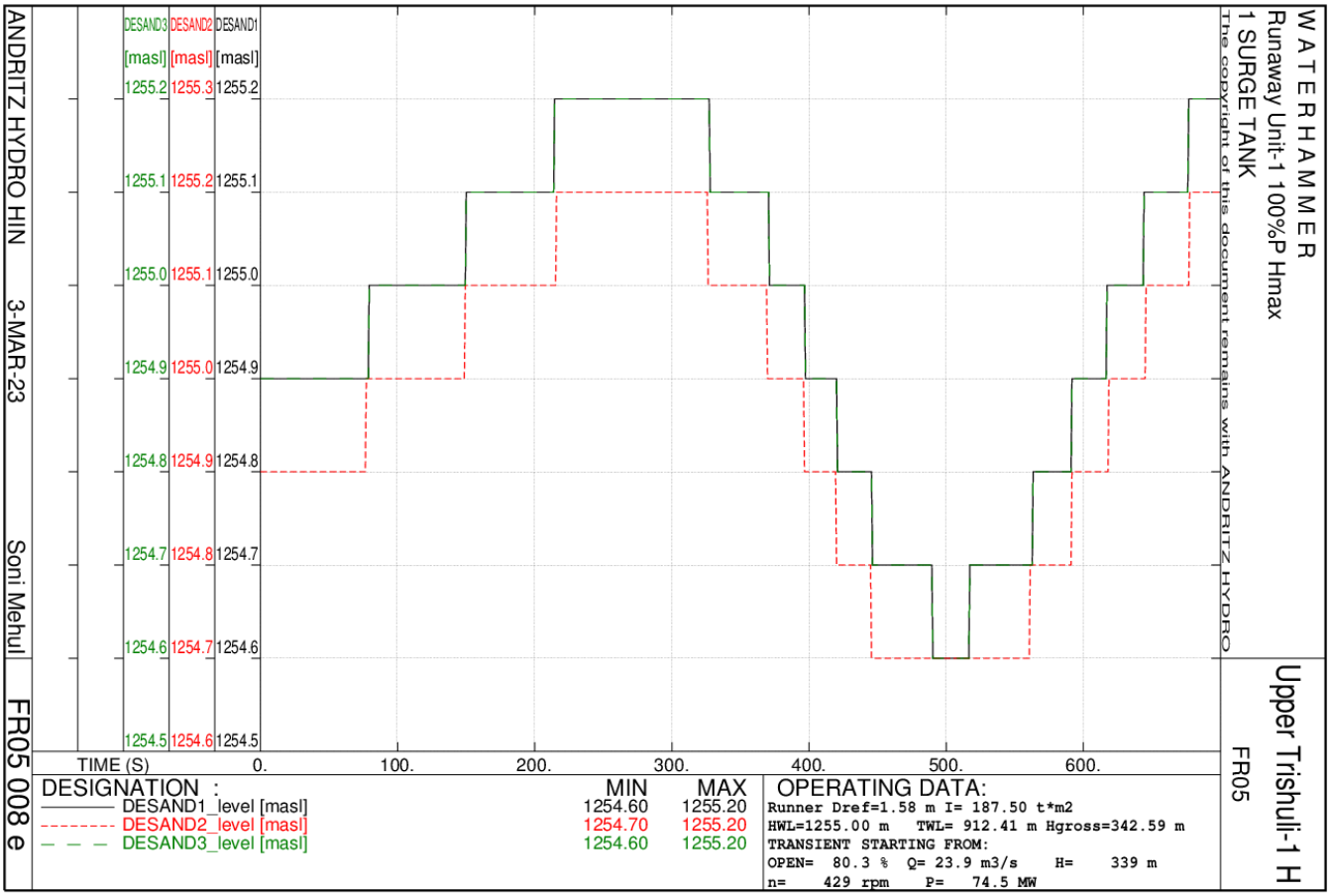
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 007 d
Upper Trishuli-1 H
FR05
DTSSHAFT [masl]
DTSSHAFT [masl]
DTSSHAFT [masl]
SSHAFT_ [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
MIN
1244.00
909.61
909.61
909.60
MAX
1262.00
917.10
917.10
917.10
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



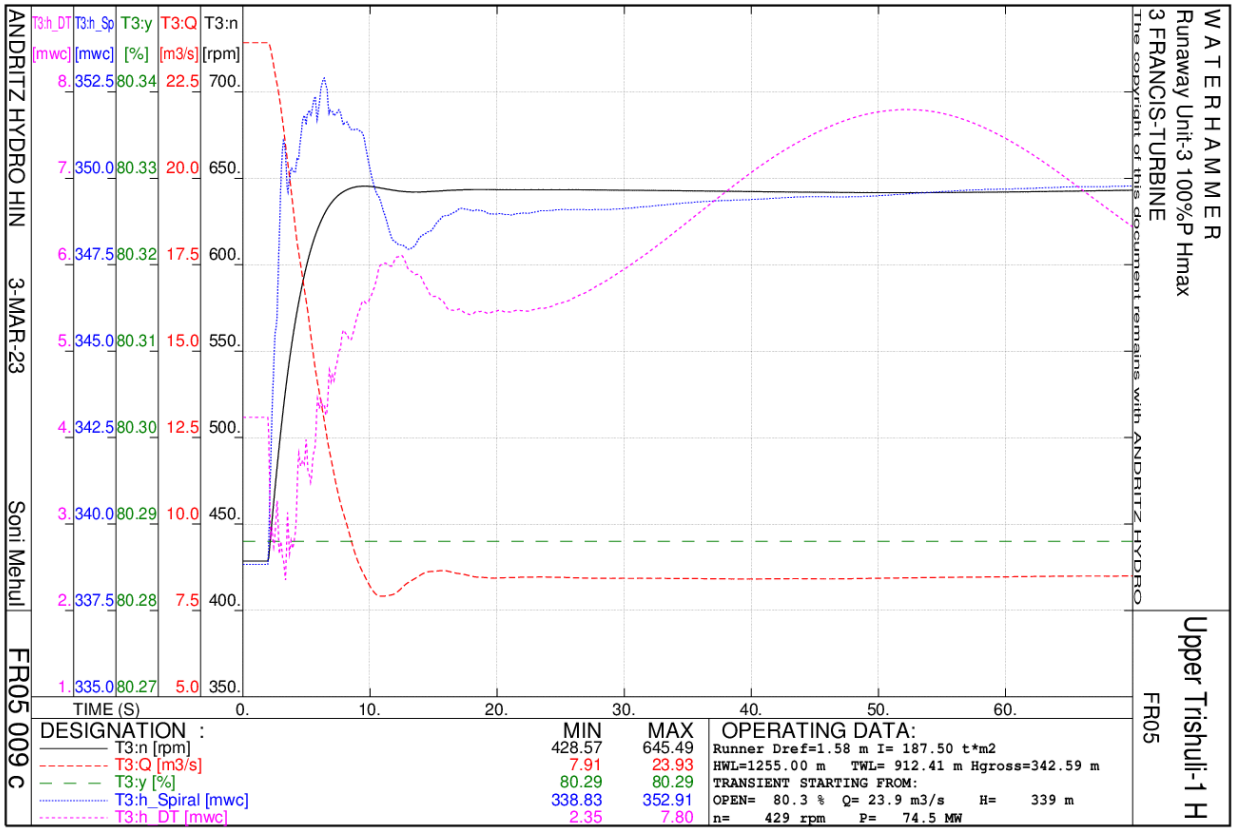
FR05 007 Runaway Unit-3 QSD-E Unit-1&2 100%P Hrated

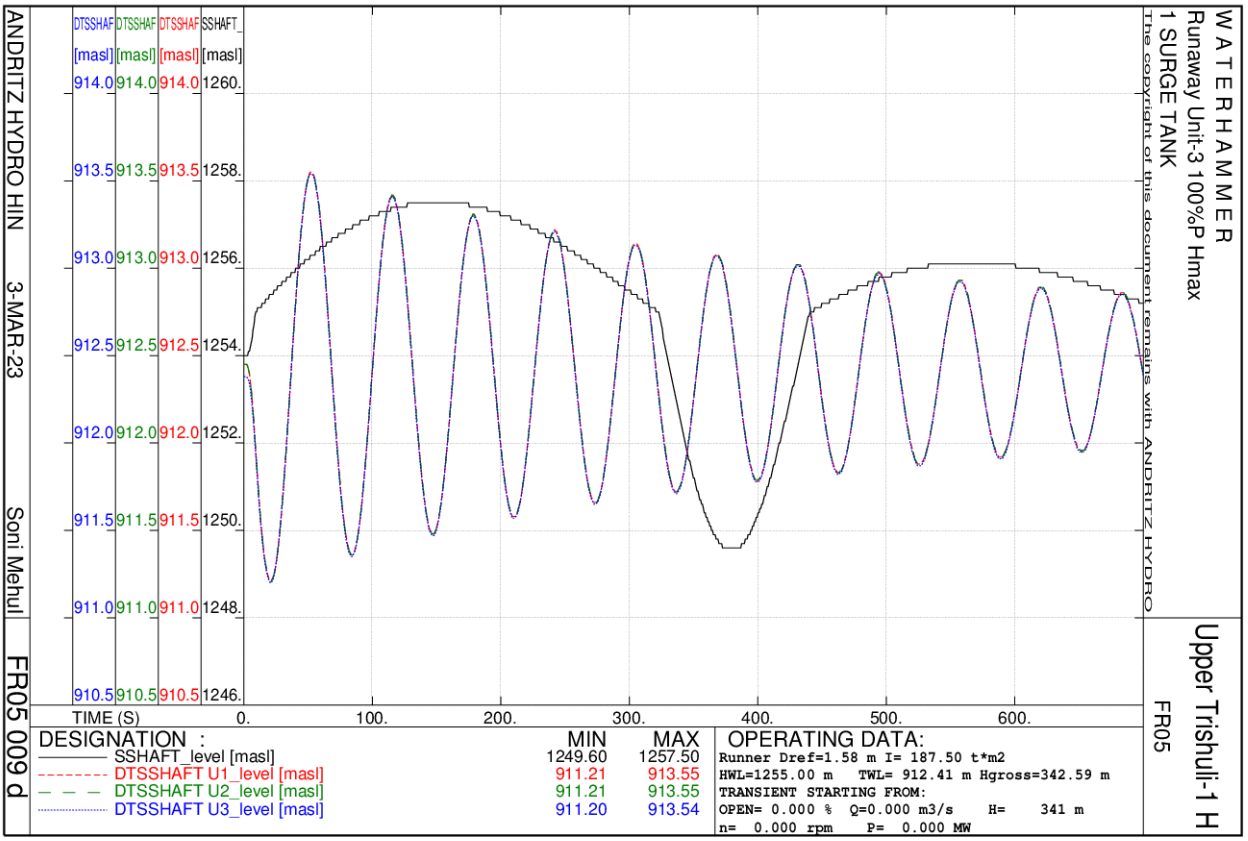

WATERHAMMER
Runaway Unit-1 100%P Hmax
1 FRANCIS-TURBINE
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 008 a
Upper Trishuli-1 H
FR05
TIME (S)
DESIGNATION :
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
T1:h_Spiral [mwc]
T1:h_DT [mwc]
MIN
MAX
428.57 645.76
7.87 23.93
80.33 80.33
338.71 353.36
2.36 7.80
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW

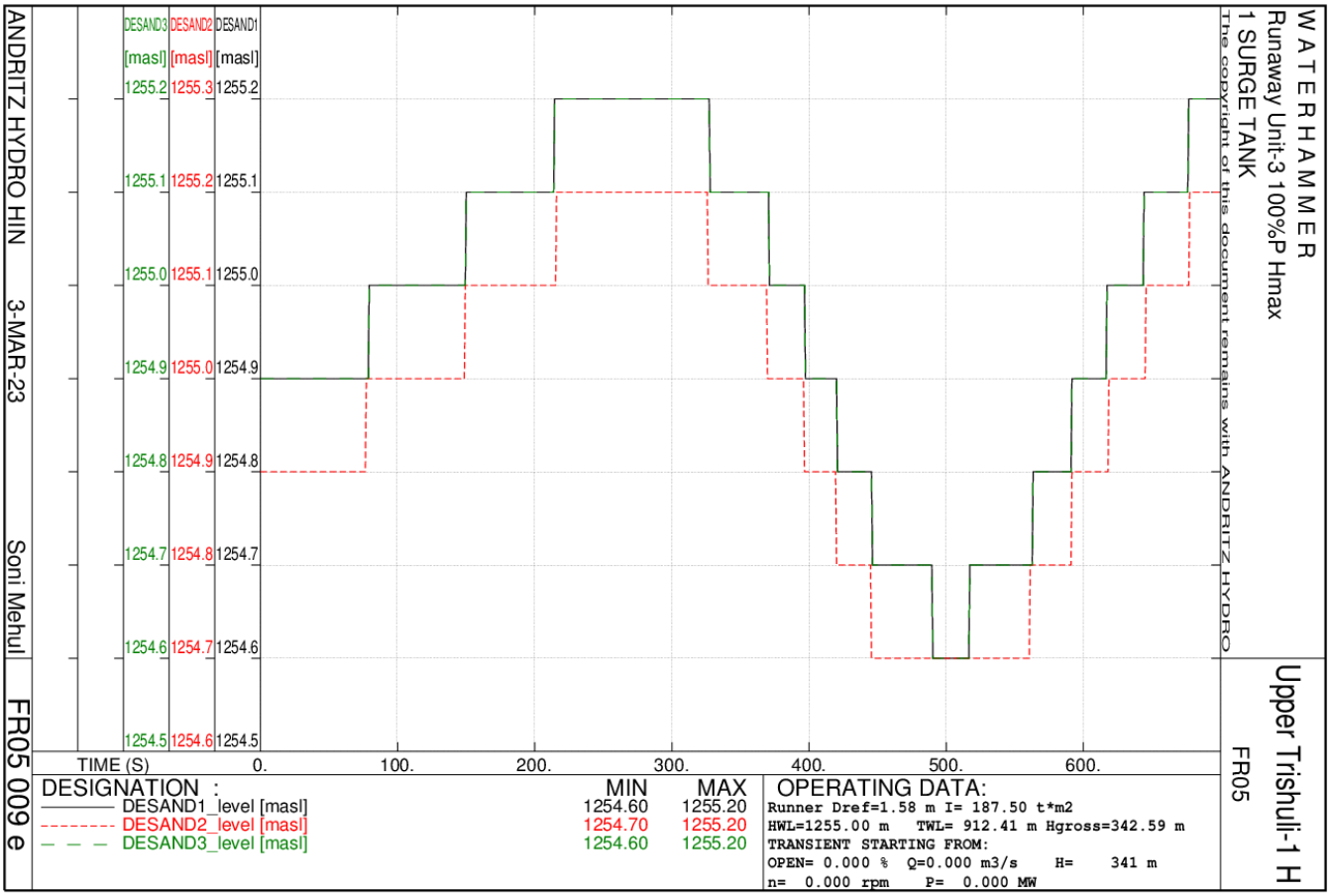

WATERHAMMER
Runaway Unit-1 100%P Hmax
1 SURGE TANK
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 008 d
Upper Trishuli-1 H
FR05
TIME (S)
DESIGNATION :
SSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
MIN
MAX
1249.60 1257.50
911.20 913.54
911.21 913.55
911.21 913.55
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW



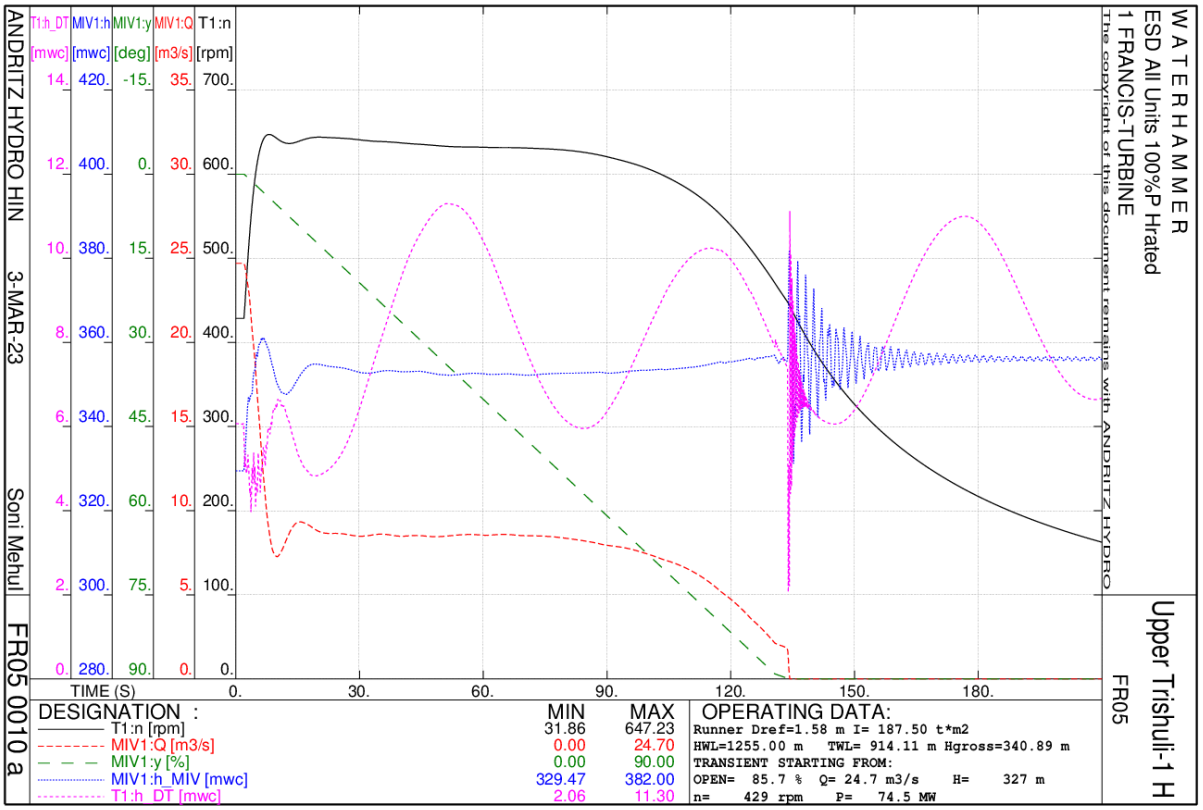
FR05 008 Runaway Unit-1 100%P Hmax

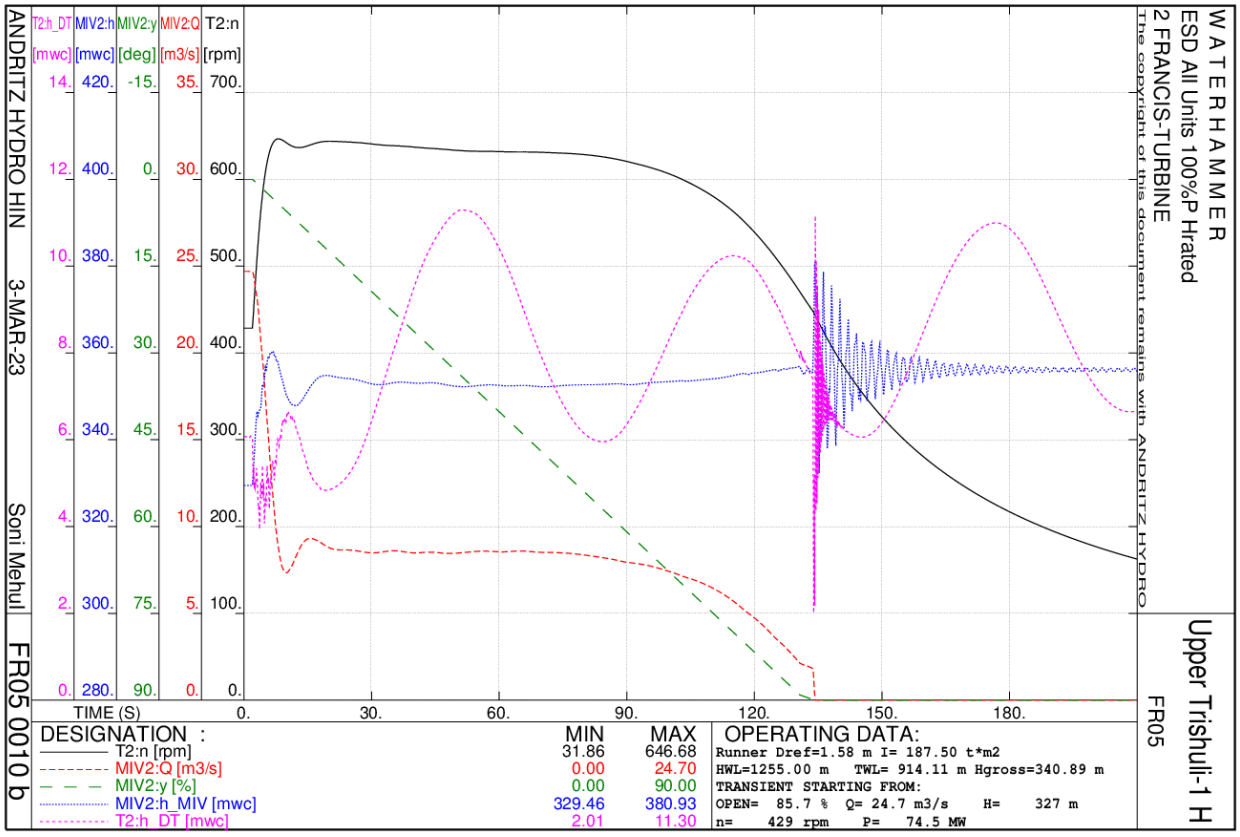

WATERHAMMER
Runaway Unit-3 100%P Hmax
3 FRANCIS-TURBINE
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 009 c
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm] 428.57 645.49
T3:Q [m3/s] 7.91 23.93
T3:y [%] 80.29 80.29
T3:h_Spiral [mwc] 338.83 352.91
T3:h_DT [mwc] 2.35 7.80
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 80.3 % Q= 23.9 m3/s H= 339 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
Runaway Unit-3 100%P Hmax
1 SURGE TANK
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 009 d
SSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] 1249.60 1257.50
DTSSHAFT U1_level [masl] 911.21 913.55
DTSSHAFT U2_level [masl] 911.21 913.55
DTSSHAFT U3_level [masl] 911.20 913.54
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 0.000 % Q=0.000 m3/s H= 341 m
n= 0.000 rpm P= 0.000 MW



FR05 009 Runaway Unit-3 100%P Hmax


WATERHAMMER
ESD All Units 100%P Hrated
1 FRANCIS-TURBINE
The copyright of this document remains with ANDRITZ HYDRO
ANDRITZ HYDRO HIN 3-MAR-23 Soni Mehul FR05 0010 a
Upper Trishuli-1 H
FR05
T1:h_DT [mwc] MIV1:h [mwc] MIV1:y [deg] MIV1:Q [m3/s] T1:n [rpm]
TIME (S)
DESIGNATION : MIN MAX
T1:n [rpm] 31.86 647.23
MIV1:Q [m3/s] 0.00 24.70
MIV1:y [%] 0.00 90.00
MIV1:h_MIV [mwc] 329.47 382.00
T1:h_DT [mwc] 2.06 11.30
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 85.7 % Q= 24.7 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
ESD All Units 100%P Hrated
2 FRANCIS-TURBINE
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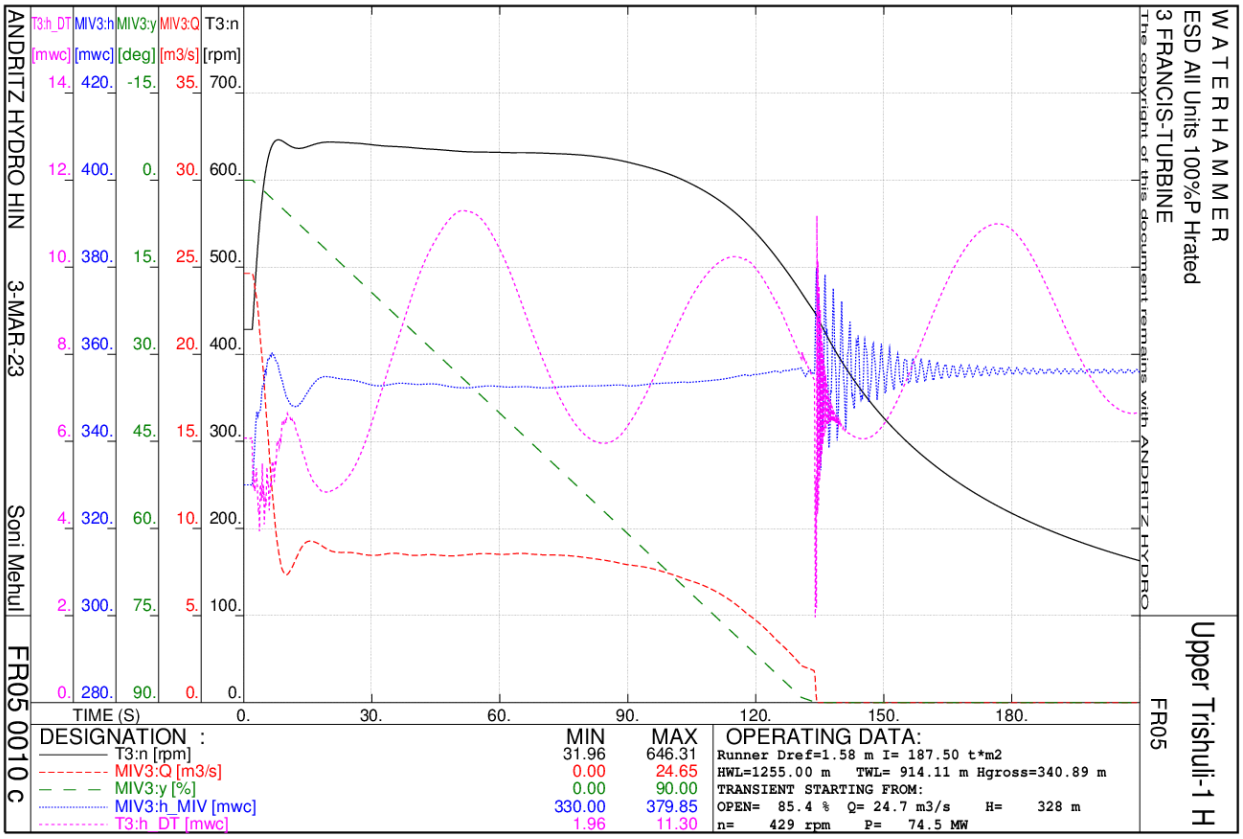
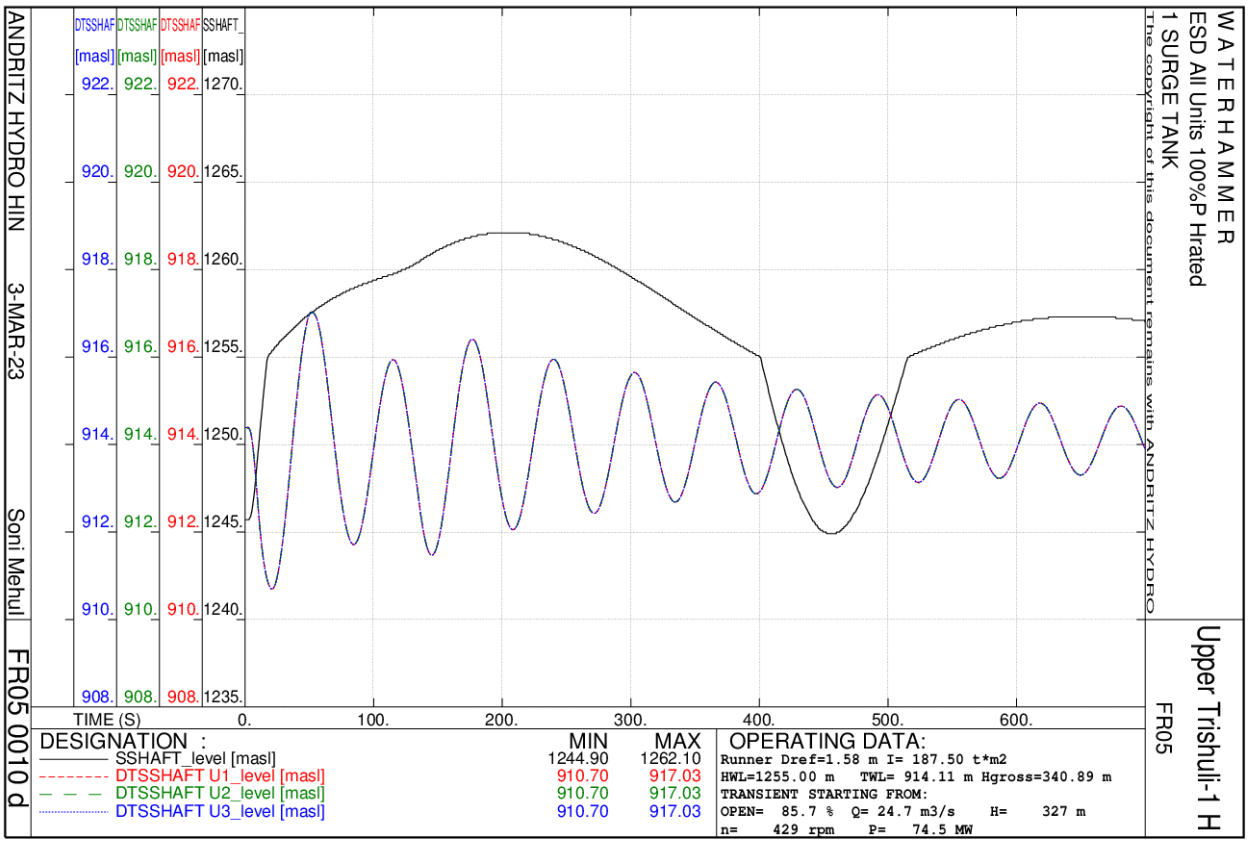
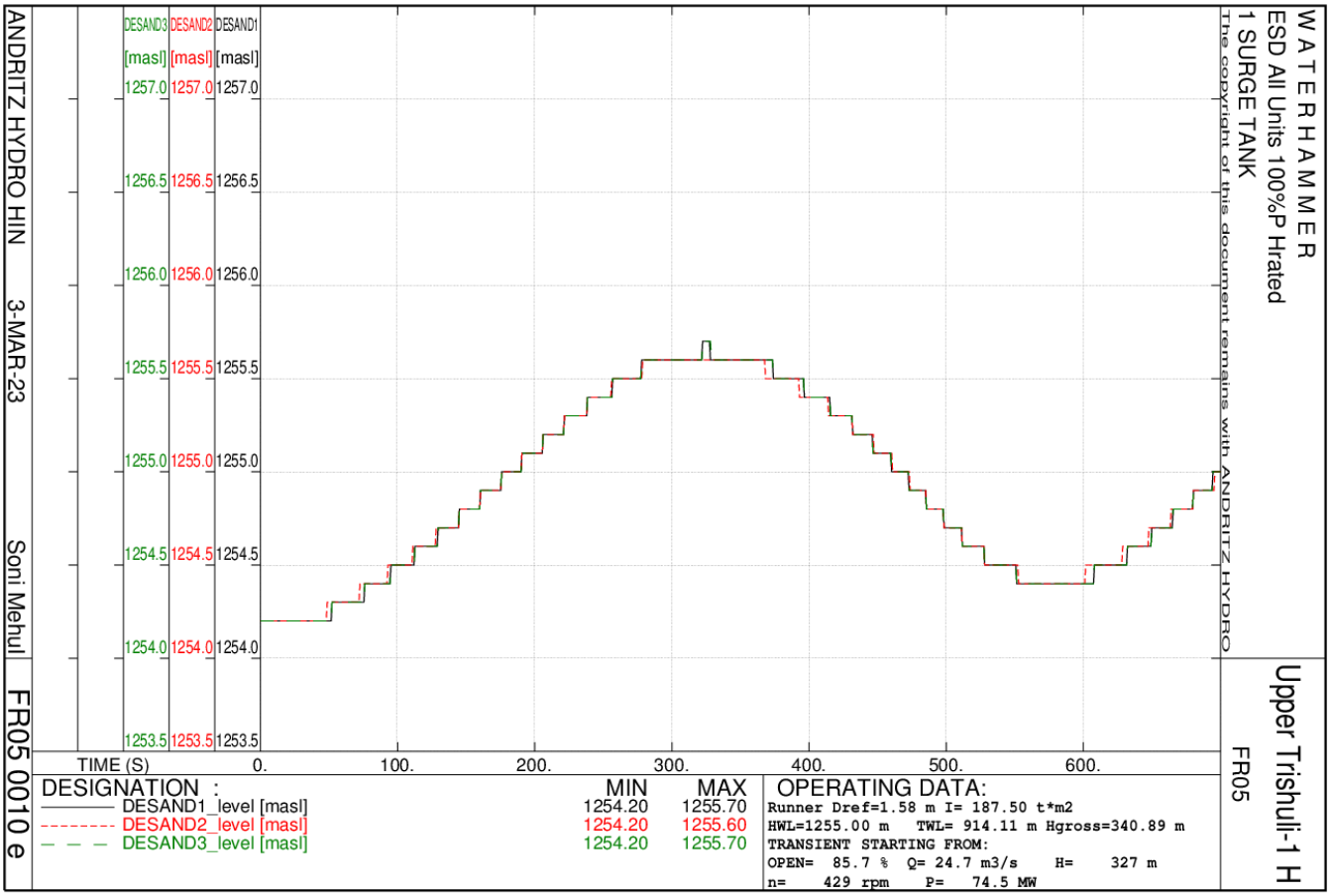
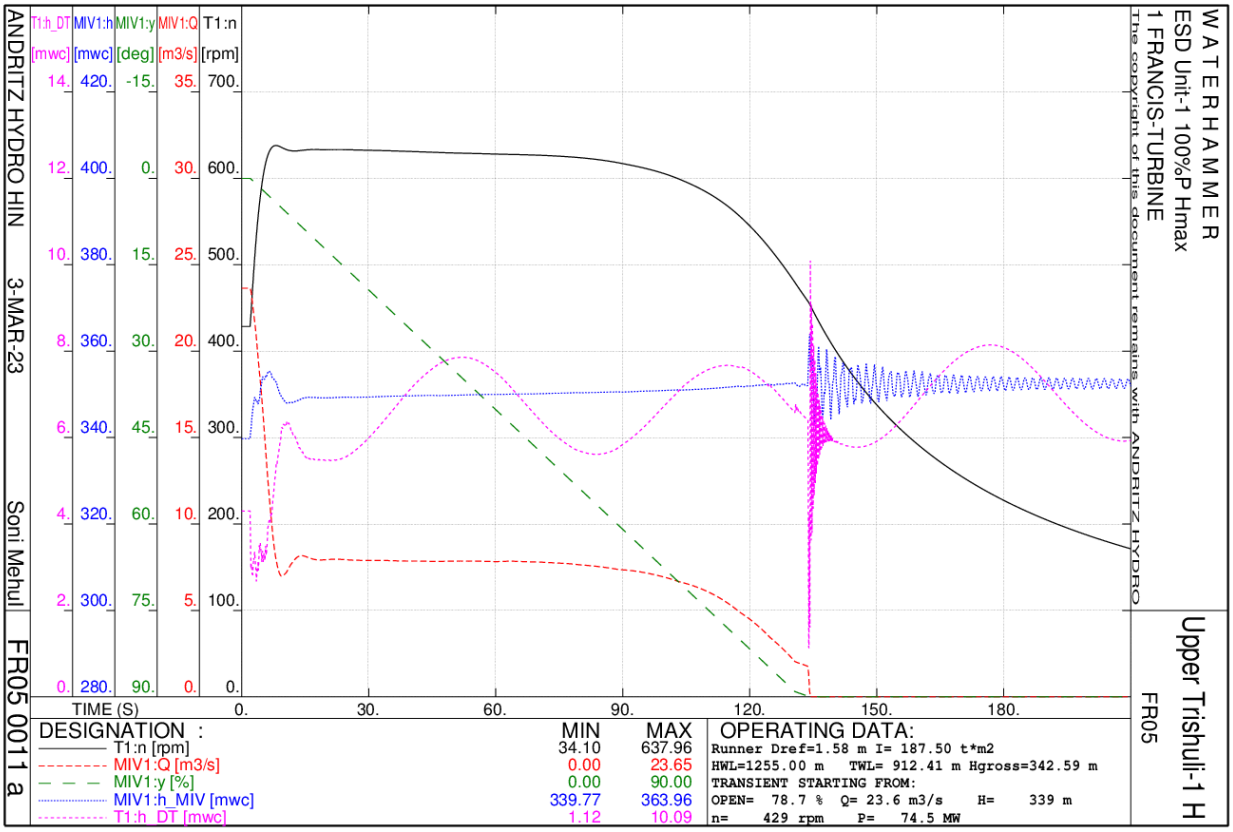
ANDRITZ HYDRO HIN 3-MAR-23 Soni Mehul FR05 0010 b
Upper Trishuli-1 H
FR05
T2:h_DT [mwc] MIV2:h [mwc] MIV2:y [deg] MIV2:Q [m3/s] T2:n [rpm]
TIME (S)
DESIGNATION : MIN MAX
T2:n [rpm] 31.86 646.68
MIV2:Q [m3/s] 0.00 24.70
MIV2:y [%] 0.00 90.00
MIV2:h_MIV [mwc] 329.46 380.93
T2:h_DT [mwc] 2.01 11.30
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 85.7 % Q= 24.7 m3/s H= 327 m
n= 429 rpm P= 74.5 MW

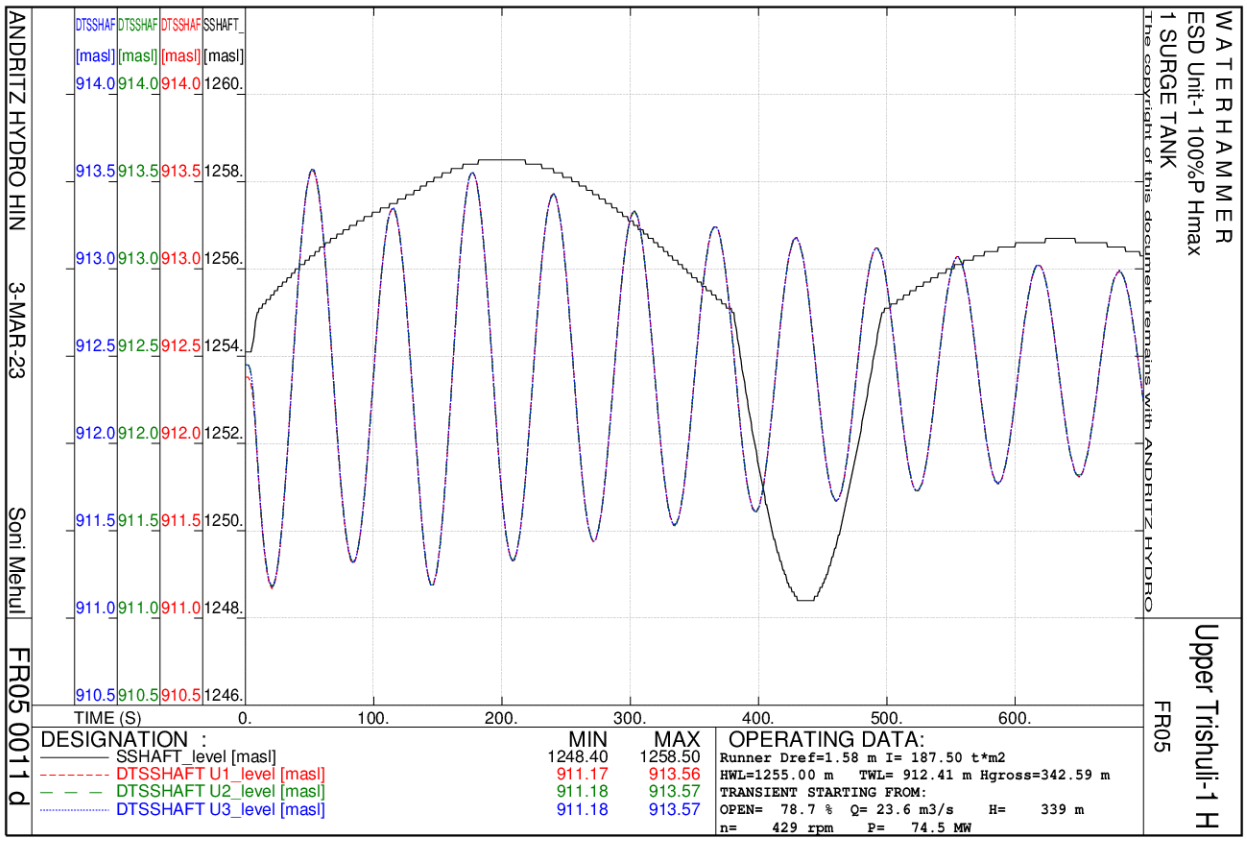

WATERHAMMER
ESD All Units 100%P Hrated
3 FRANCIS-TURBINE
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0010 c
Upper Trishuli-1 H
FR05
T3:h_DT [mwc]
MIV3:h [mwc]
MIV3:y [deg]
MIV3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION : MIN MAX
T3:n [rpm] 31.96 646.31
MIV3:Q [m3/s] 0.00 24.65
MIV3:y [%] 0.00 90.00
MIV3:h_MIV [mwc] 330.00 379.85
T3:h_DT [mwc] 1.96 11.30
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 85.4 % Q= 24.7 m3/s H= 328 m
n= 429 rpm P= 74.5 MW

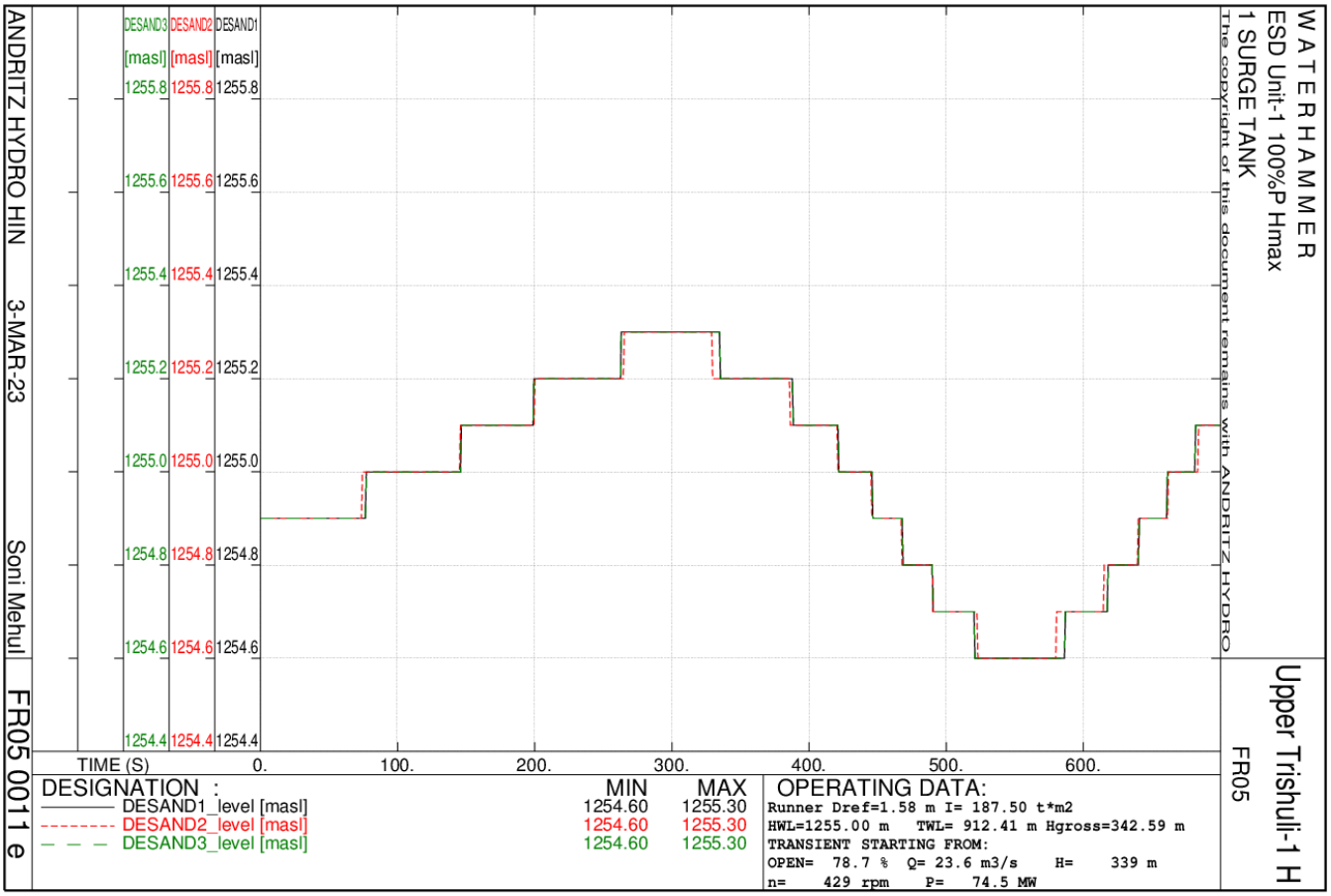

WATERHAMMER
ESD All Units 100%P Hrated
1 SURGE TANK
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0010 d
Upper Trishuli-1 H
FR05
SSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
TIME (S)
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1244.90 1262.10
DTSSHAFT U1_level [masl] 910.70 917.03
DTSSHAFT U2_level [masl] 910.70 917.03
DTSSHAFT U3_level [masl] 910.70 917.03
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 85.7 % Q= 24.7 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



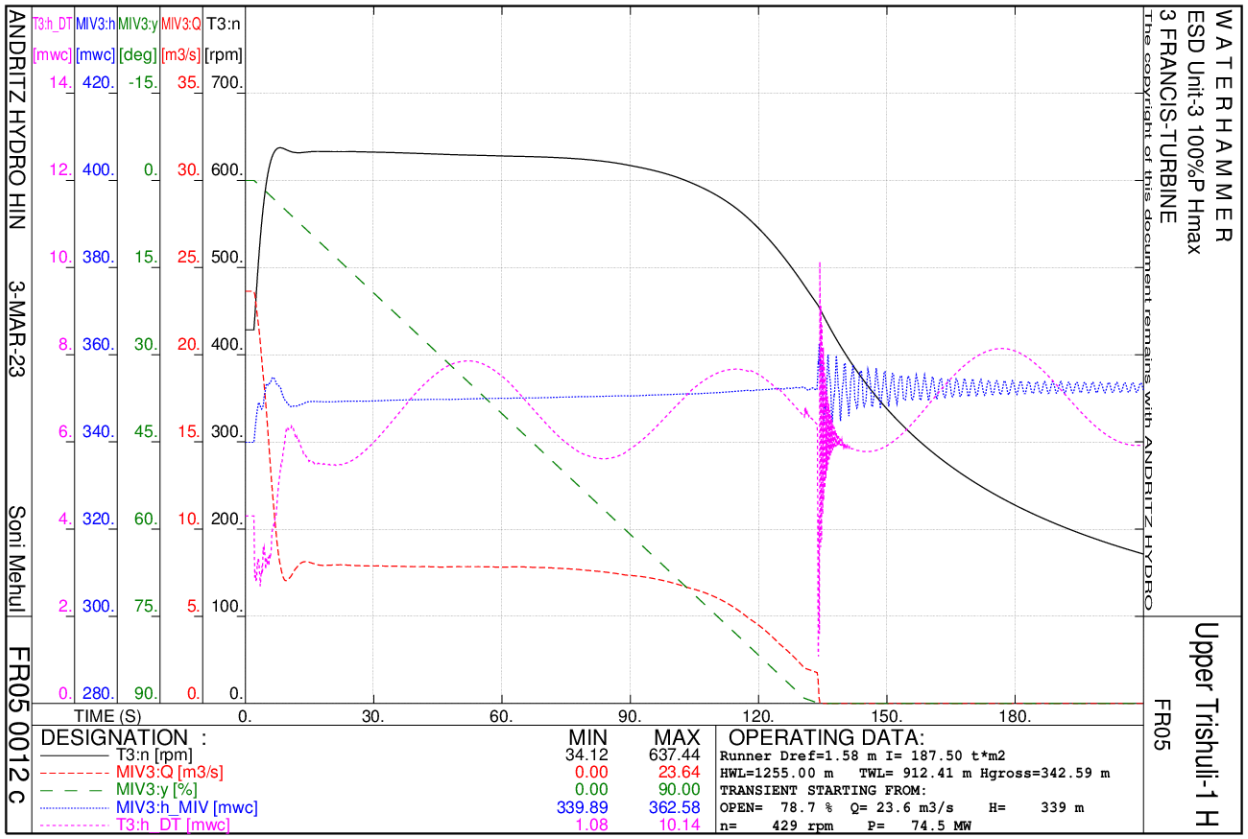
FR05 0010 ESD All Units 100%P Hrated

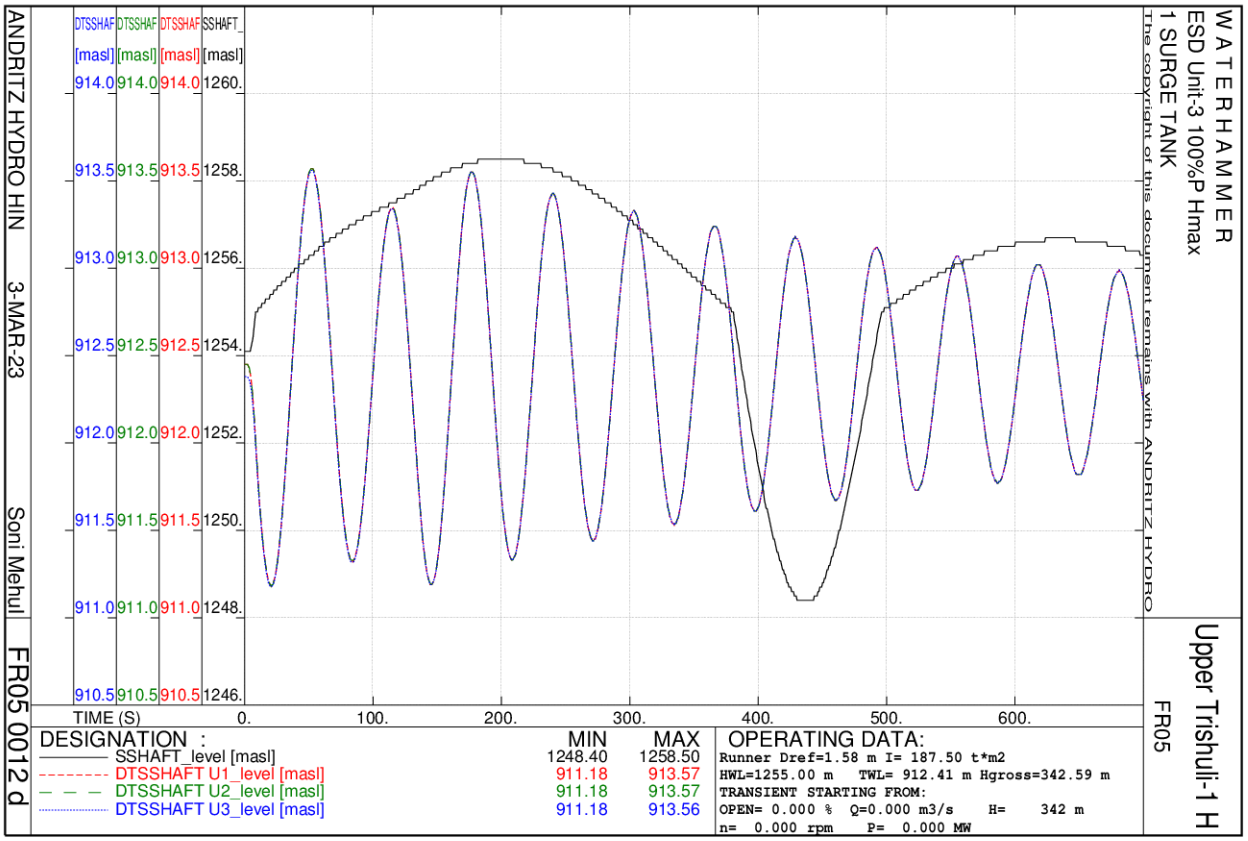

WATERHAMMER
ESD Unit-1 100%P Hmax
1 FRANCIS-TURBINE
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0011 a
T1:h_DT [mwc]
MIV1:h [mwc]
MIV1:y [deg]
MIV1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION : MIN MAX
T1:n [rpm] 34.10 637.96
MIV1:Q [m3/s] 0.00 23.65
MIV1:y [%] 0.00 90.00
MIV1:h_MIV [mwc] 339.77 363.96
T1:h_DT [mwc] 1.12 10.09
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 78.7 % Q= 23.6 m3/s H= 339 m
n= 429 rpm P= 74.5 MW

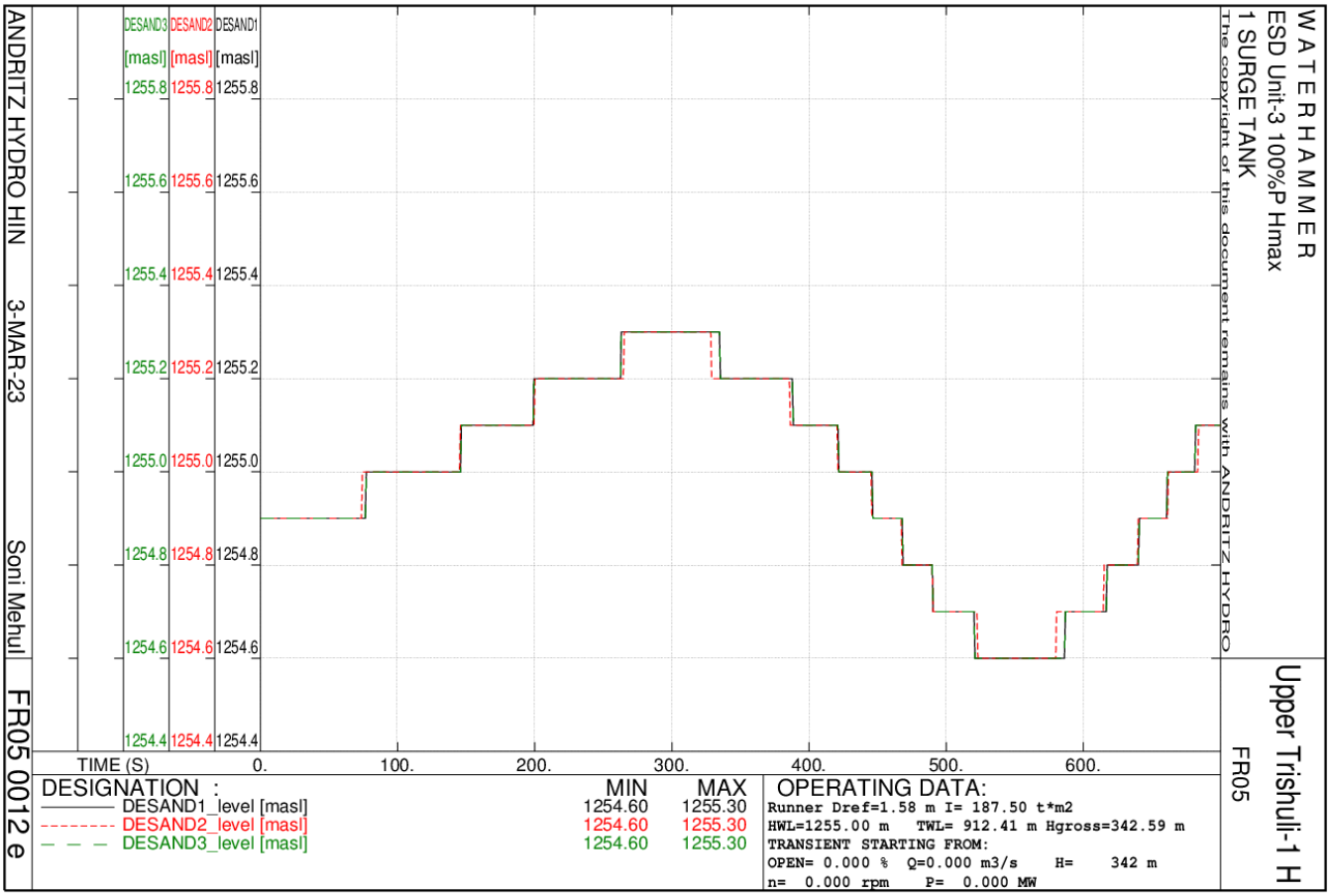

WATERHAMMER
ESD Unit-1 100%P Hmax
1 SURGE TANK
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0011 d
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1248.40 1258.50
DTSSHAFT U1_level [masl] 911.17 913.56
DTSSHAFT U2_level [masl] 911.18 913.57
DTSSHAFT U3_level [masl] 911.18 913.57
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 78.7 % Q= 23.6 m3/s H= 339 m
n= 429 rpm P= 74.5 MW



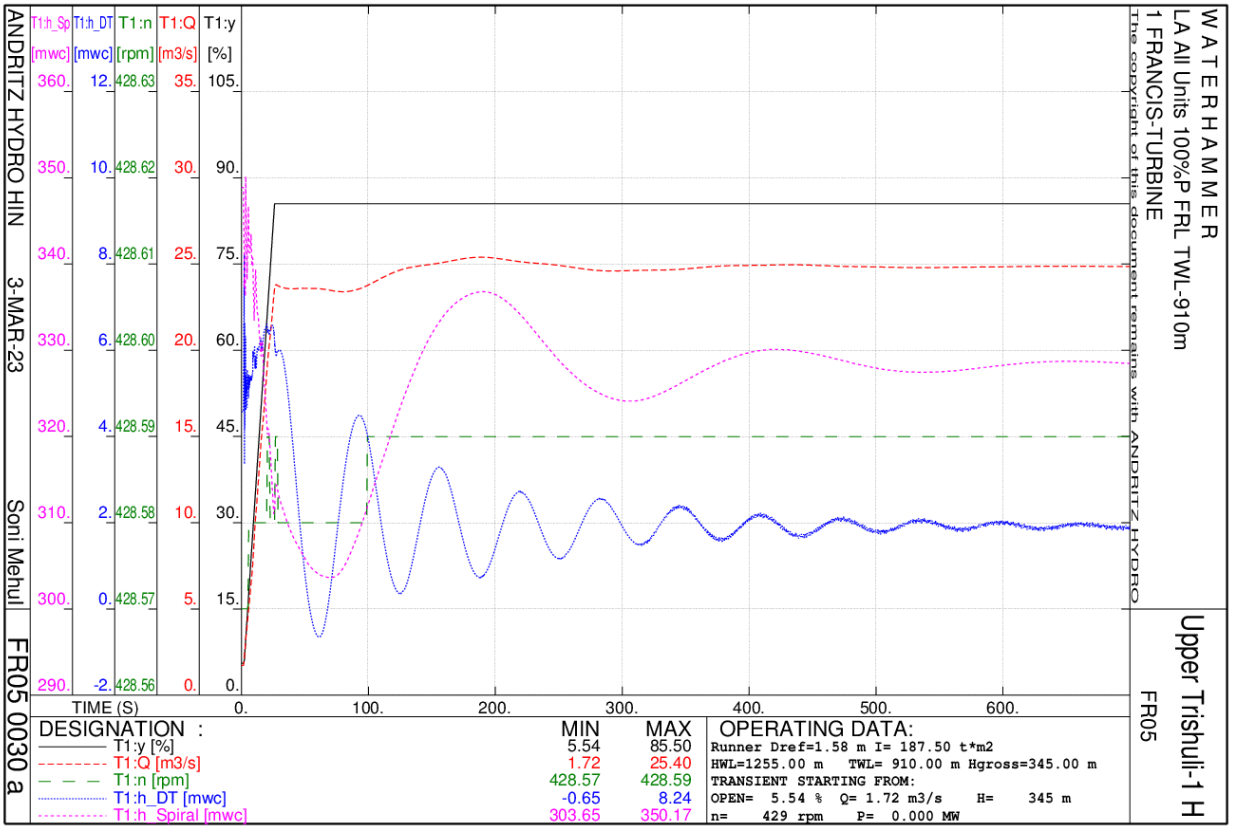
FR05 0011 ESD Unit-1 100%P Hmax


WATERHAMMER
ESD Unit-3 100%P Hmax
3 FRANCIS-TURBINE
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0012 c
T3:h_DT [mwc]
MIV3:h [mwc]
MIV3:y [deg]
MIV3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm] MIN 34.12 MAX 637.44
MIV3:Q [m3/s] 0.00 23.64
MIV3:y [%] 0.00 90.00
MIV3:h_MIV [mwc] 339.89 362.58
T3:h_DT [mwc] 1.08 10.14
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 78.7 % Q= 23.6 m3/s H= 339 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
ESD Unit-3 100%P Hmax
1 SURGE TANK
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0012 d
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1248.40 MAX 1258.50
DTSSHAFT U1_level [masl] 911.18 913.57
DTSSHAFT U2_level [masl] 911.18 913.57
DTSSHAFT U3_level [masl] 911.18 913.56
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 912.41 m Hgross=342.59 m
TRANSIENT STARTING FROM:
OPEN= 0.000 % Q=0.000 m3/s H= 342 m
n= 0.000 rpm P= 0.000 MW



FR05 0012 ESD Unit-3 100%P Hmax


WATERHAMMER
LA All Units 100%P FRL TWL-910m
1 FRANCIS-TURBINE
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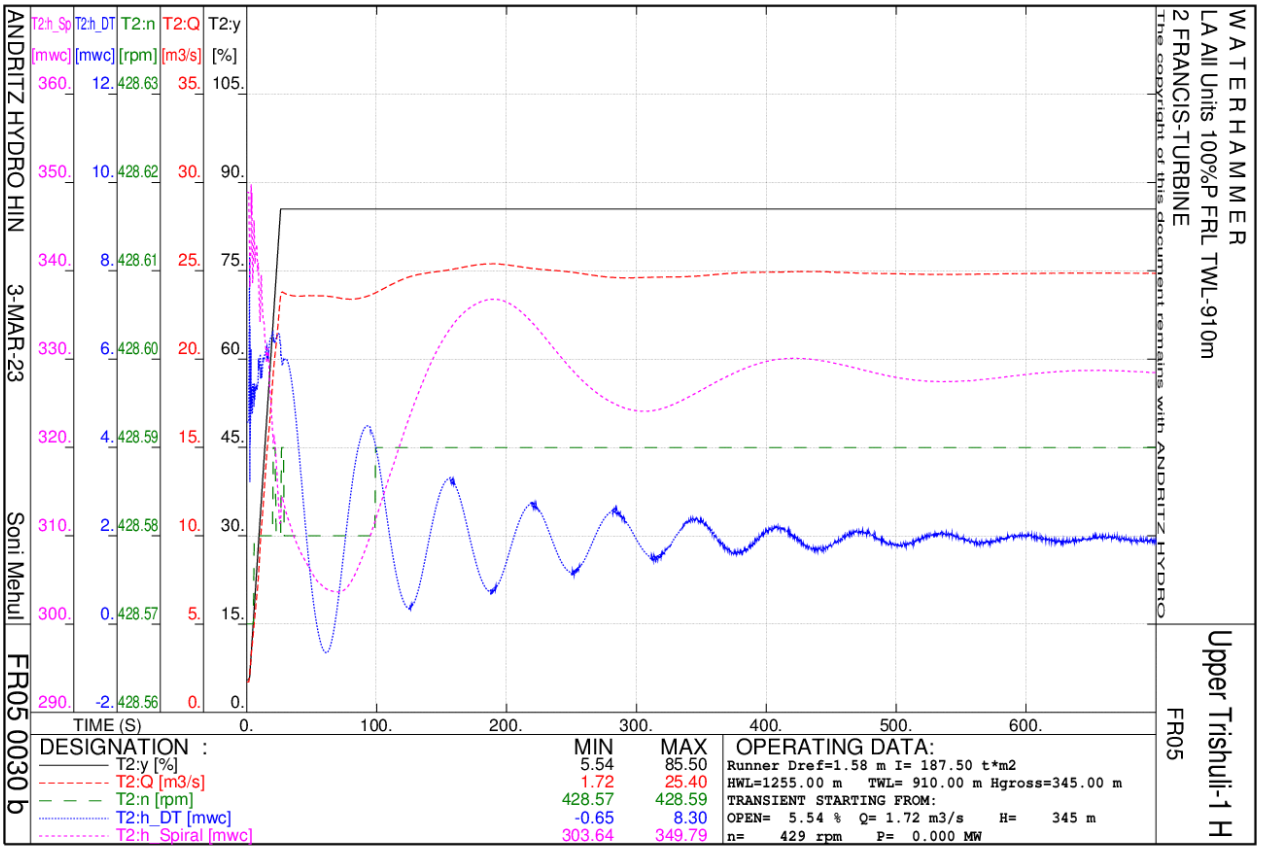
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0030 a
Upper Trishuli-1 H
FR05
T1:h_Sp [mwc] T1:h_DT [mwc] T1:n [rpm] T1:Q [m3/s] T1:y [%]
360. 12. 428.63 35. 105.
350. 10. 428.62 30. 90.
340. 8. 428.61 25. 75.
330. 6. 428.60 20. 60.
320. 4. 428.59 15. 45.
310. 2. 428.58 10. 30.
300. 0. 428.57 5. 15.
290. -2. 428.56 0. 0.
TIME (S) 0. 100. 200. 300. 400. 500. 600.
DESIGNATION : MIN MAX
T1:y [%] 5.54 85.50
T1:Q [m3/s] 1.72 25.40
T1:n [rpm] 428.57 428.59
T1:h_DT [mwc] -0.65 8.24
T1:h_Spiral [mwc] 303.65 350.17
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-910m
2 FRANCIS-TURBINE
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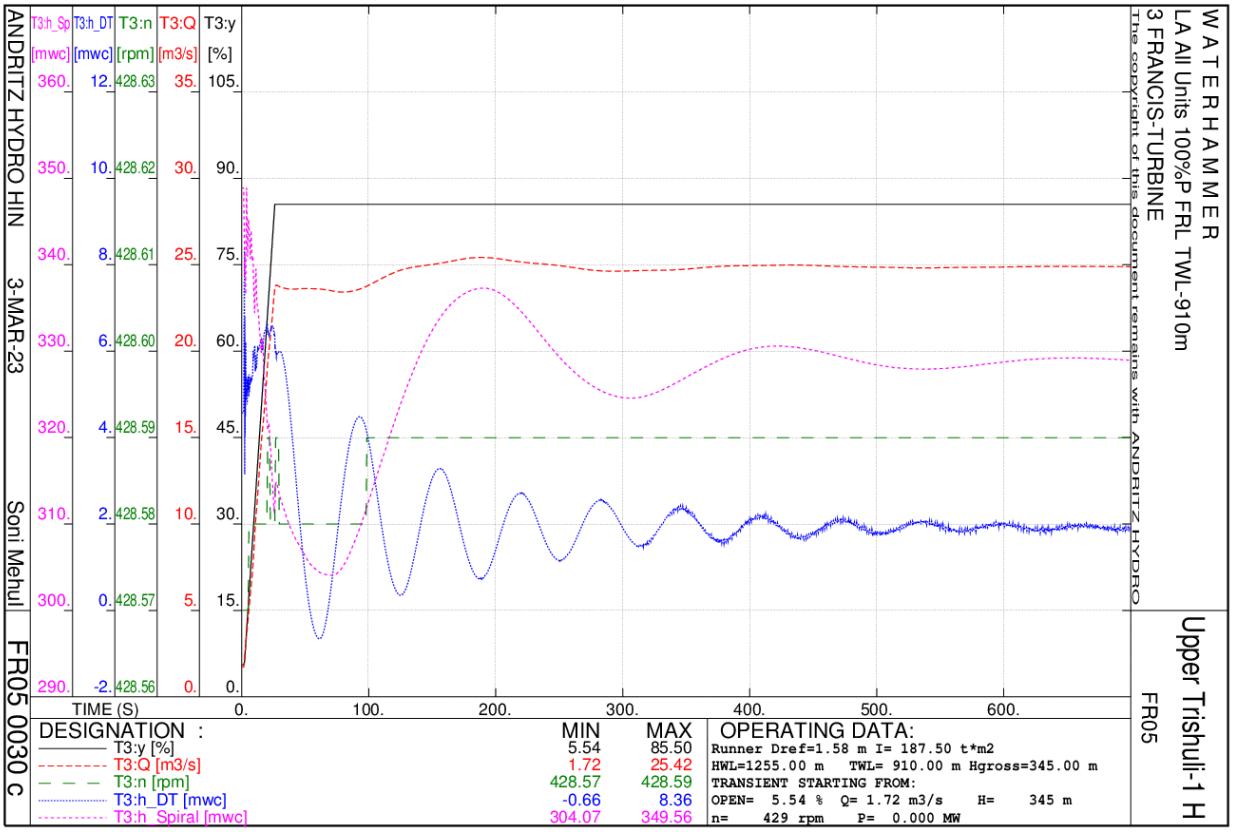
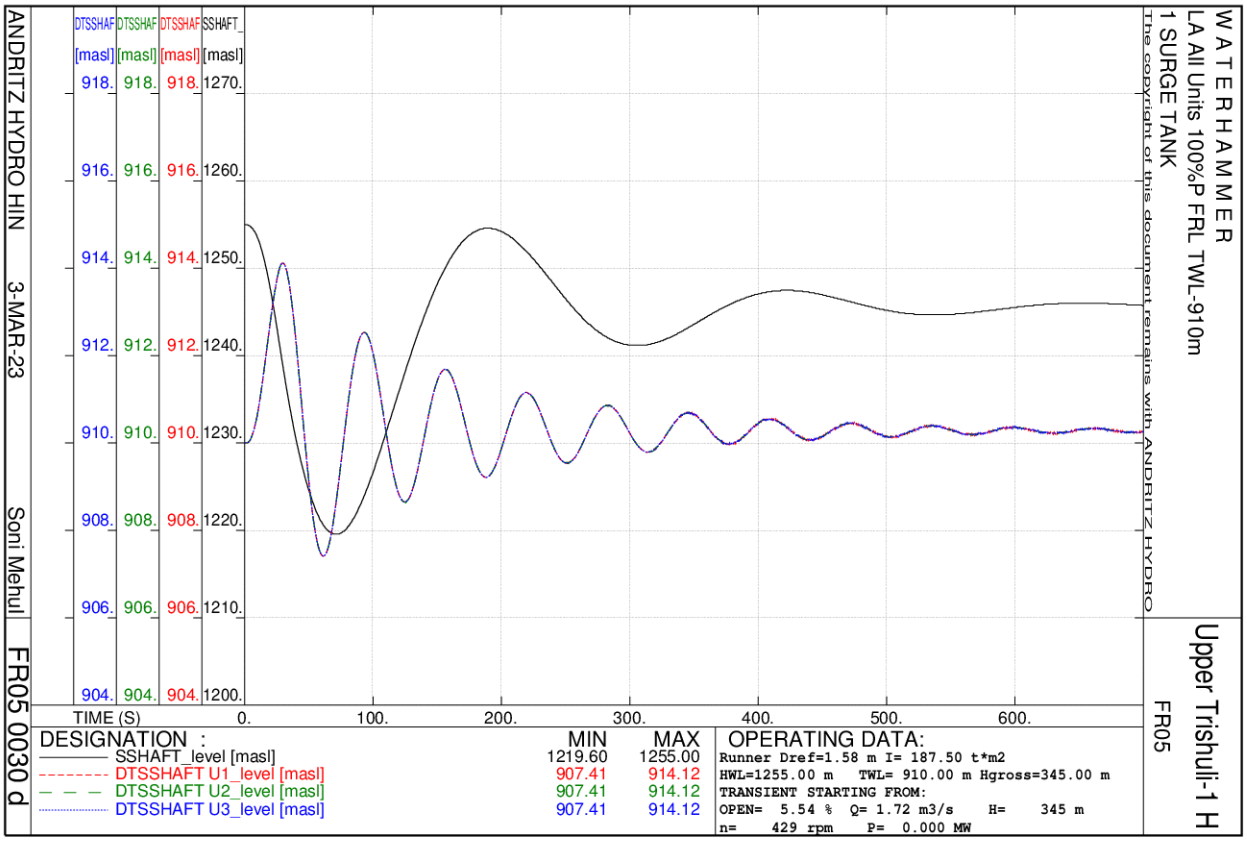
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0030 b
Upper Trishuli-1 H
FR05
T2:h_Sp [mwc] T2:h_DT [mwc] T2:n [rpm] T2:Q [m3/s] T2:y [%]
360. 12. 428.63 35. 105.
350. 10. 428.62 30. 90.
340. 8. 428.61 25. 75.
330. 6. 428.60 20. 60.
320. 4. 428.59 15. 45.
310. 2. 428.58 10. 30.
300. 0. 428.57 5. 15.
290. -2. 428.56 0. 0.
TIME (S) 0. 100. 200. 300. 400. 500. 600.
DESIGNATION : MIN MAX
T2:y [%] 5.54 85.50
T2:Q [m3/s] 1.72 25.40
T2:n [rpm] 428.57 428.59
T2:h_DT [mwc] -0.65 8.30
T2:h_Spiral [mwc] 303.64 349.79
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-910m
3 FRANCIS-TURBINE
The copyright of this document remains with ANDRITZ HYDRO
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0030 c
T3:h_Sp [mwc]
T3:h_DT [mwc]
T3:n [rpm]
T3:Q [m3/s]
T3:y [%]
TIME (S)
DESIGNATION :
T3:y [%] MIN 5.54 MAX 85.50
T3:Q [m3/s] MIN 1.72 MAX 25.42
T3:n [rpm] MIN 428.57 MAX 428.59
T3:h_DT [mwc] MIN -0.66 MAX 8.36
T3:h_Spiral [mwc] MIN 304.07 MAX 349.56
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-910m
1 SURGE TANK
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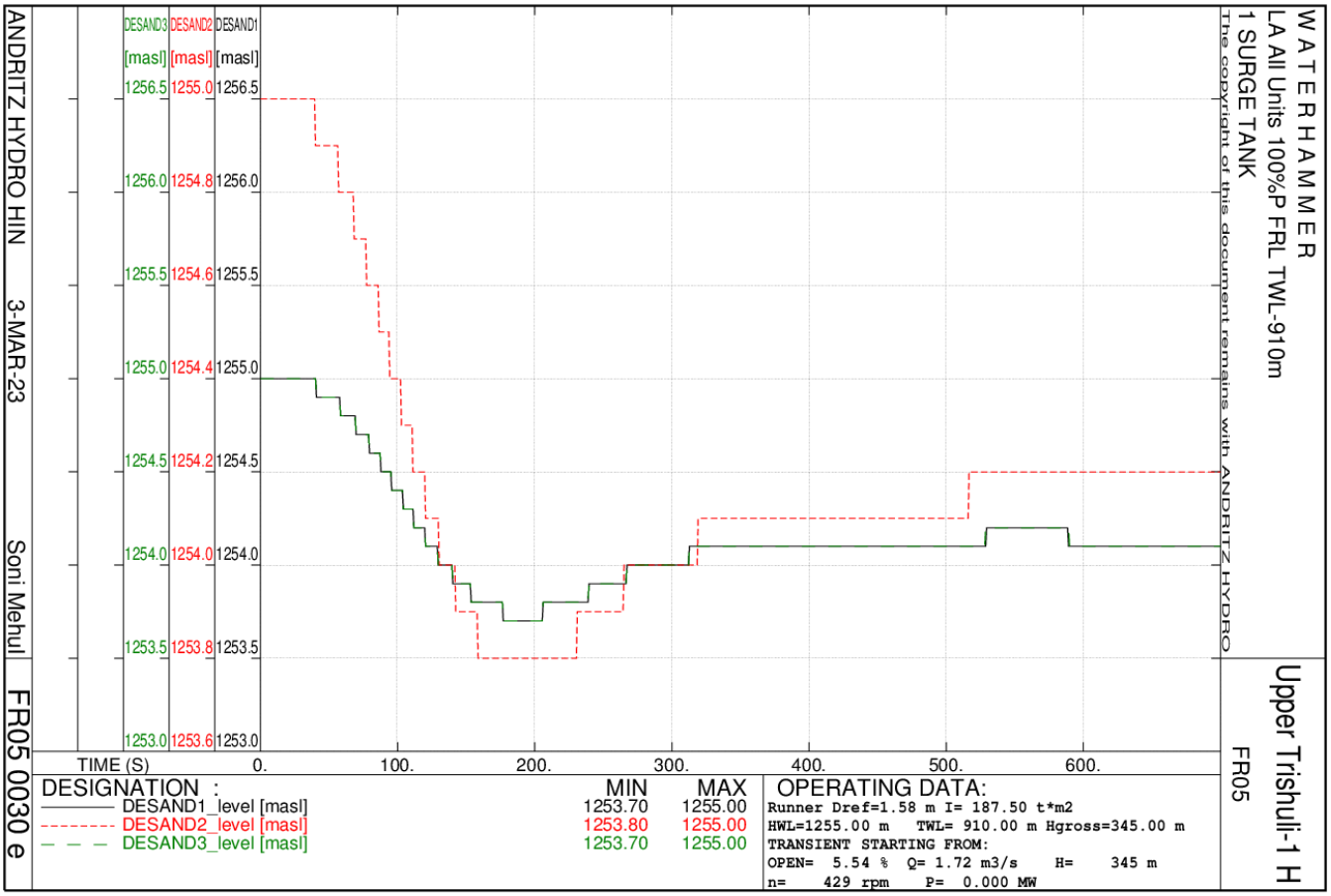
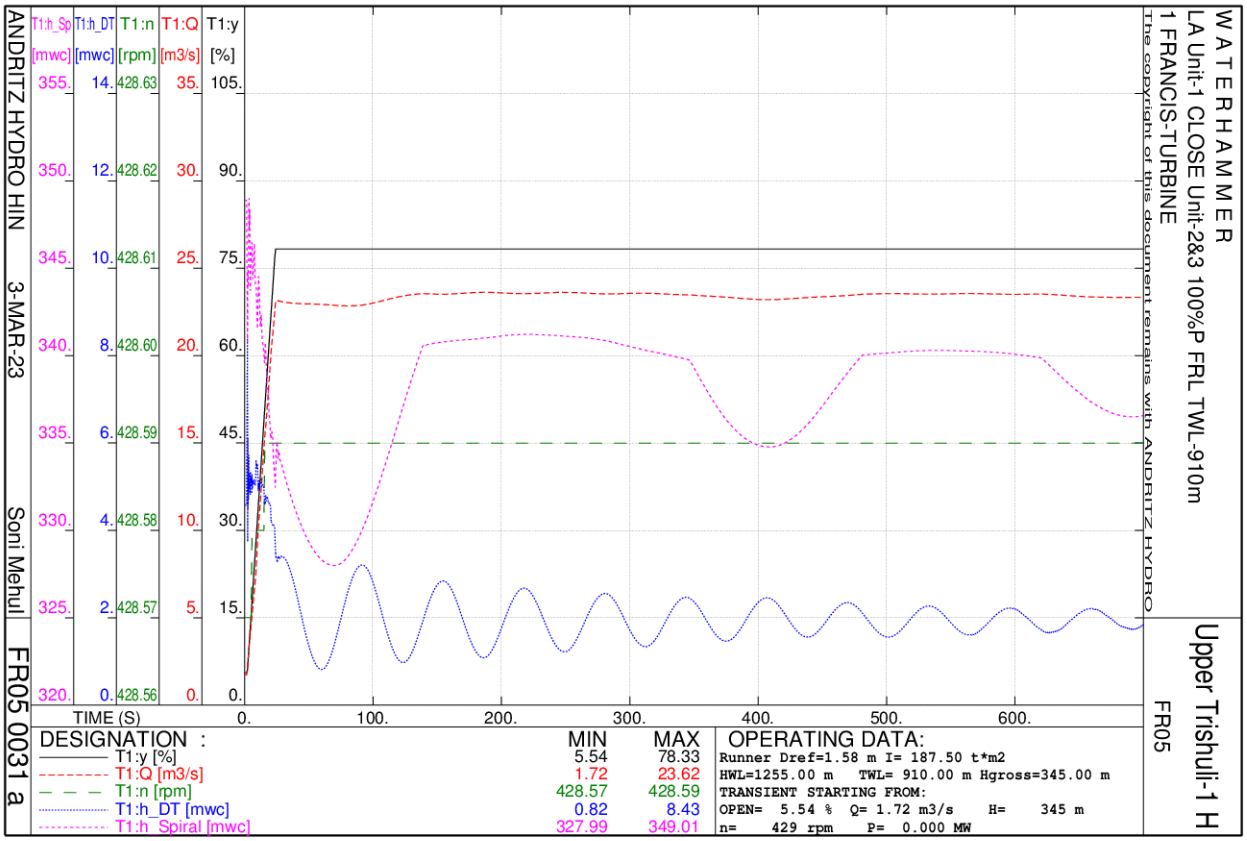
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0030 d
DTSSHAFT [masl]
SSHAFT [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1219.60 MAX 1255.00
DTSSHAFT U1_level [masl] MIN 907.41 MAX 914.12
DTSSHAFT U2_level [masl] MIN 907.41 MAX 914.12
DTSSHAFT U3_level [masl] MIN 907.41 MAX 914.12
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW



FR05 0030 LA All Units 100%P FRL TWL-910m


WATERHAMMER
LA Unit-1 CLOSE Unit-2&3 100%P FRL TWL-910m
1 FRANCIS-TURBINE
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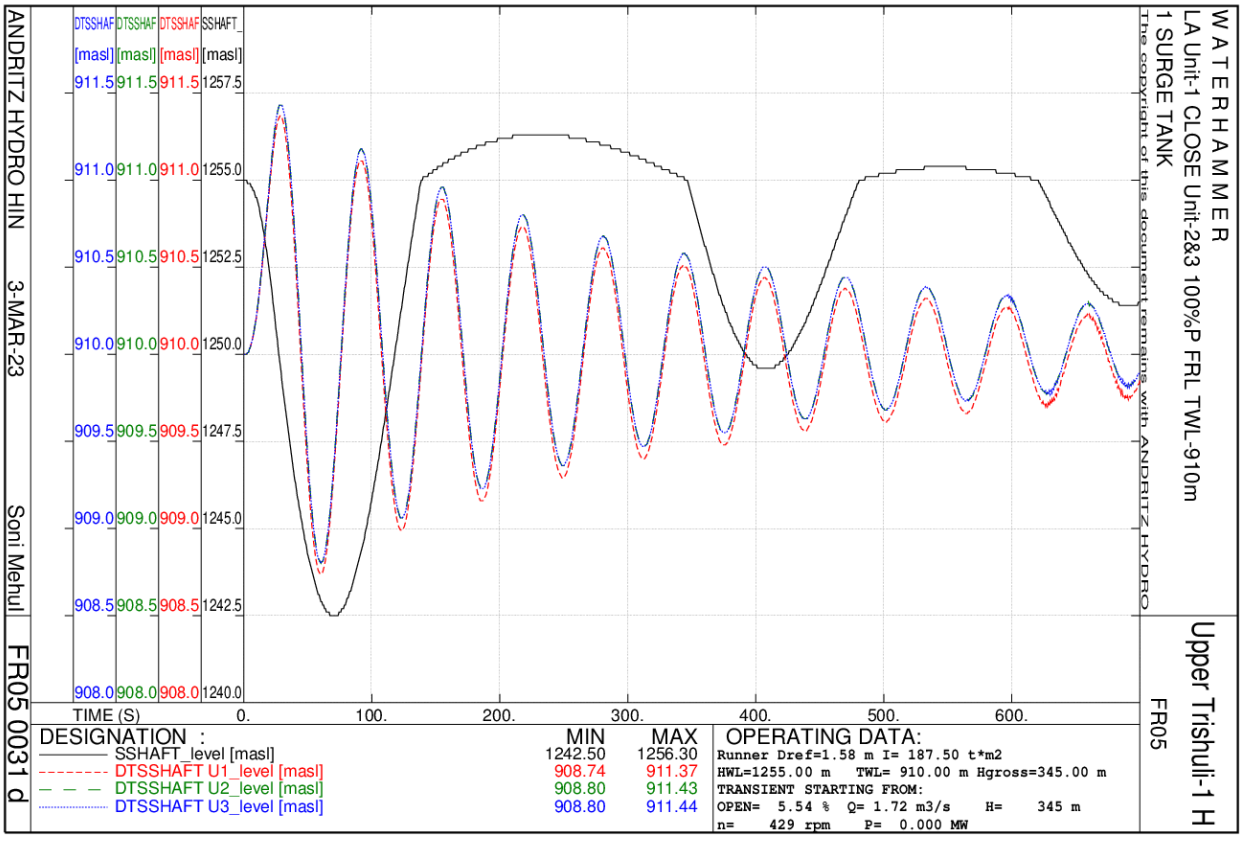
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0031 a
Upper Trishuli-1 H
FR05
T1:h_Sp [mwc]
T1:h_DT [mwc]
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
TIME (S)
DESIGNATION :
T1:y [%] MIN 5.54 MAX 78.33
T1:Q [m3/s] 1.72 23.62
T1:n [rpm] 428.57 428.59
T1:h_DT [mwc] 0.82 8.43
T1:h_Spiral [mwc] 327.99 349.01
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 CLOSE Unit-2&3 100%P FRL TWL-910m
1 SURGE TANK
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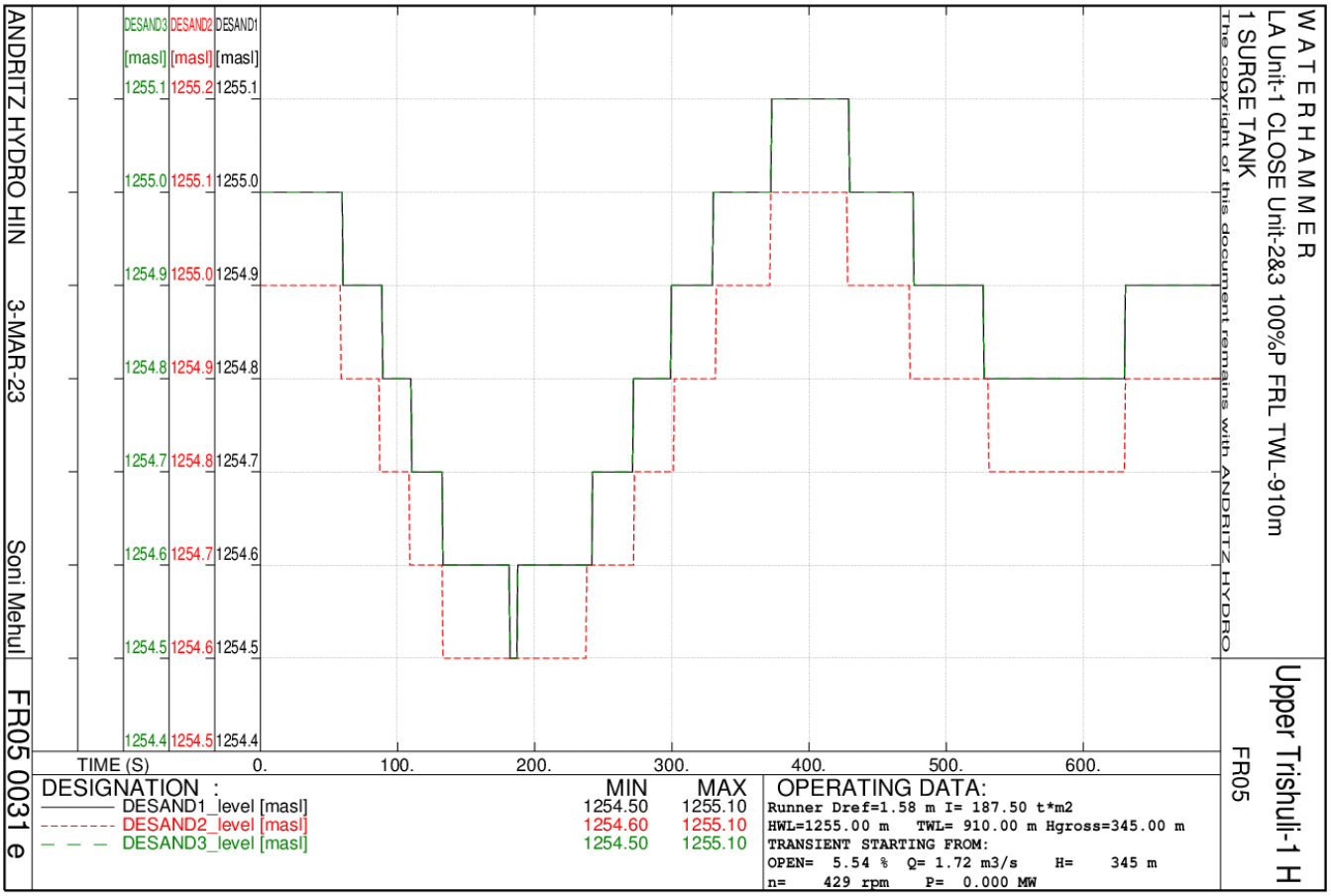
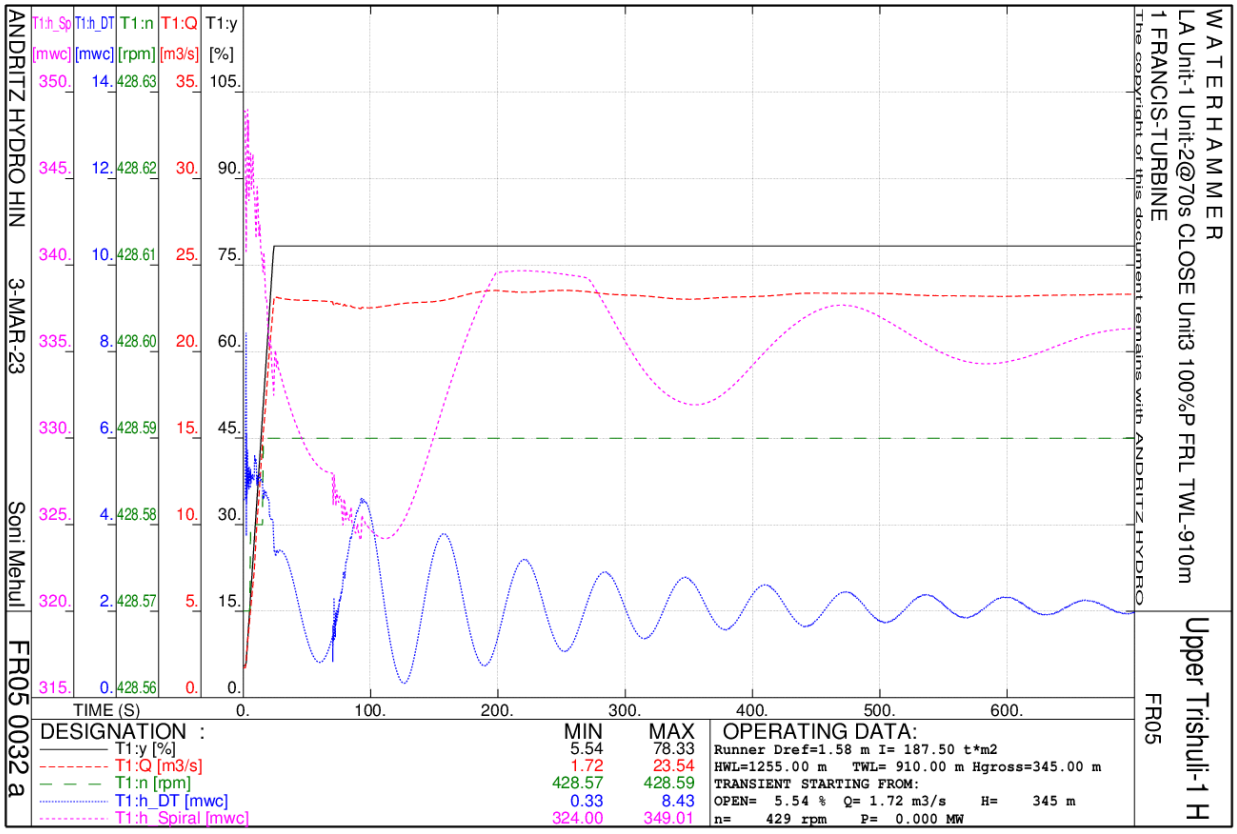
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0031 d
Upper Trishuli-1 H
FR05
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1242.50 MAX 1256.30
DTSSHAFT U1_level [masl] 908.74 911.37
DTSSHAFT U2_level [masl] 908.80 911.43
DTSSHAFT U3_level [masl] 908.80 911.44
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW



FR05 0031 LA Unit-1 CLOSE Unit-2&3 100%P FRL TWL-910m


WATERHAMMER
LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m
1 FRANCIS-TURBINE
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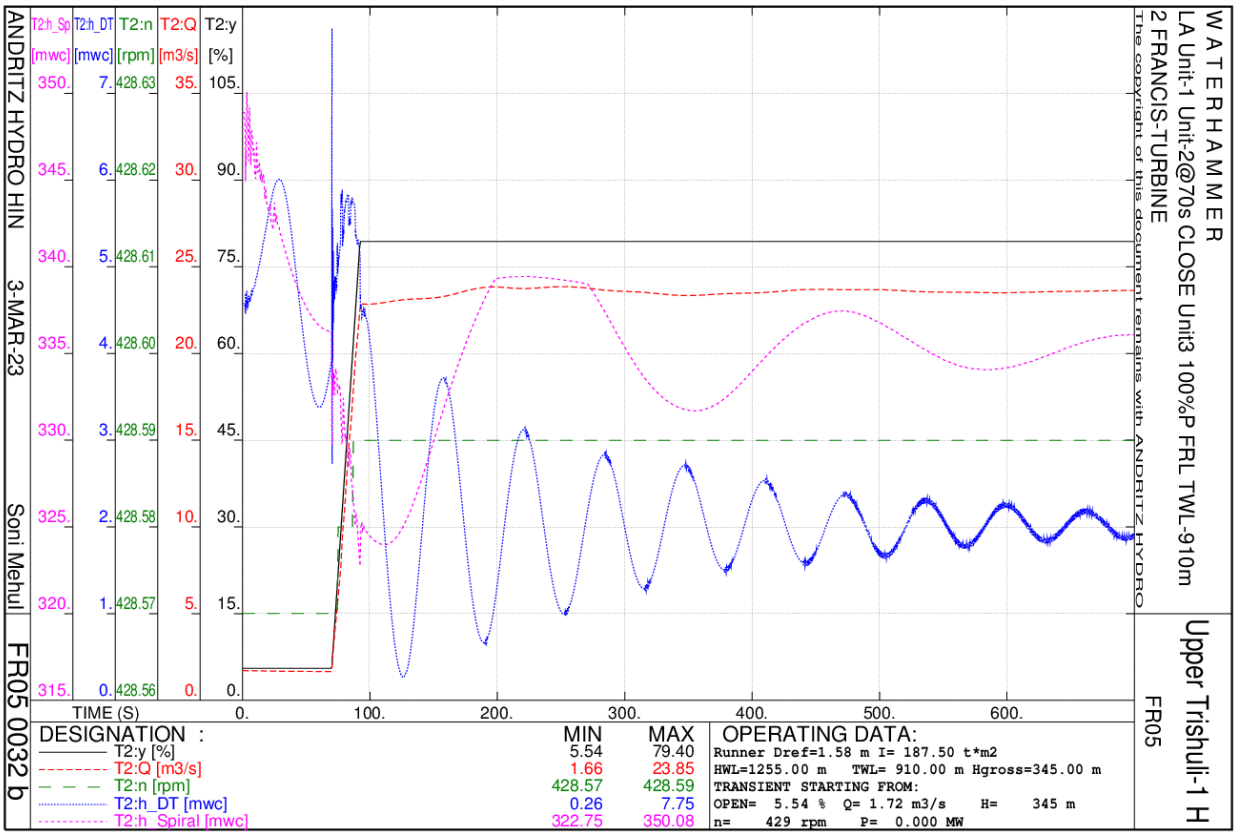
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0032 a
T1:h_Sp [mwc]
T1:h_DT [mwc]
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
TIME (S)
DESIGNATION :
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
T1:h_DT [mwc]
T1:h_Spiral [mwc]
MIN
MAX
5.54 78.33
1.72 23.54
428.57 428.59
0.33 8.43
324.00 349.01
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m
2 FRANCIS-TURBINE
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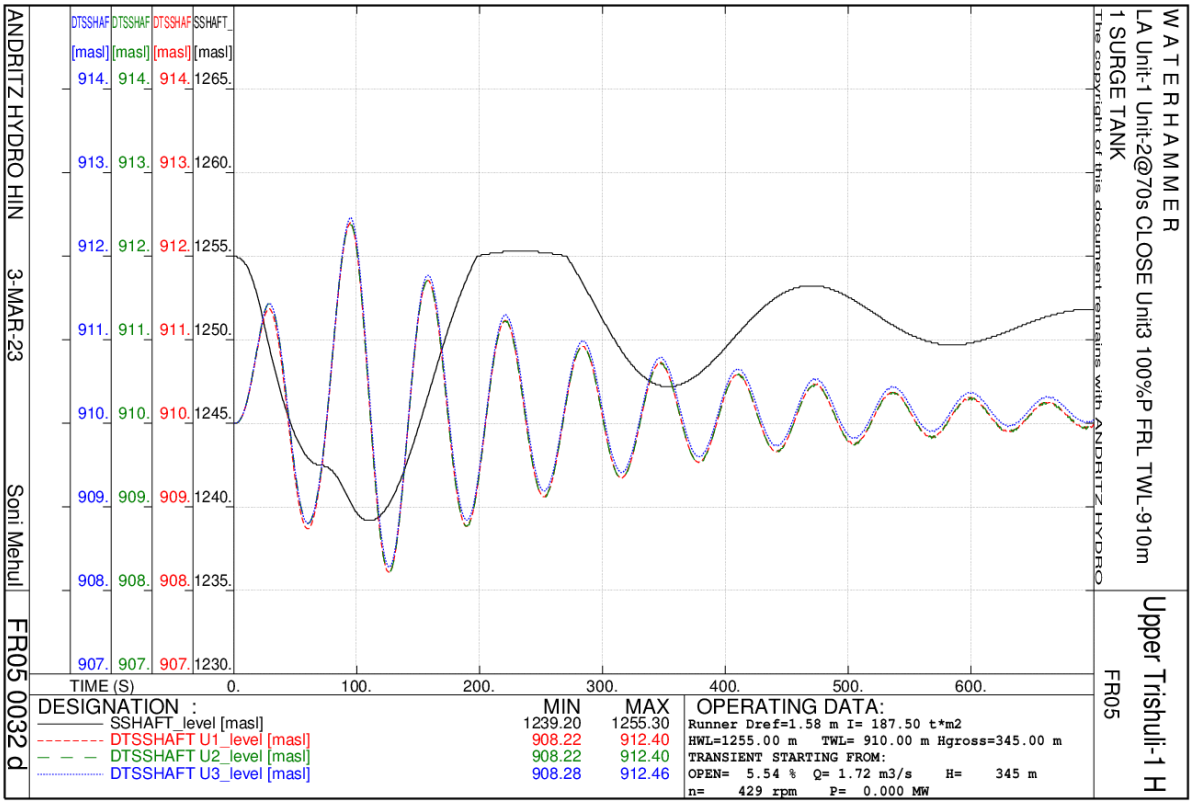
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0032 b
T2:h_Sp [mwc]
T2:h_DT [mwc]
T2:n [rpm]
T2:Q [m3/s]
T2:y [%]
TIME (S)
DESIGNATION :
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
T2:h_DT [mwc]
T2:h_Spiral [mwc]
MIN
MAX
5.54 79.40
1.66 23.85
428.57 428.59
0.26 7.75
322.75 350.08
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m
1 SURGE TANK
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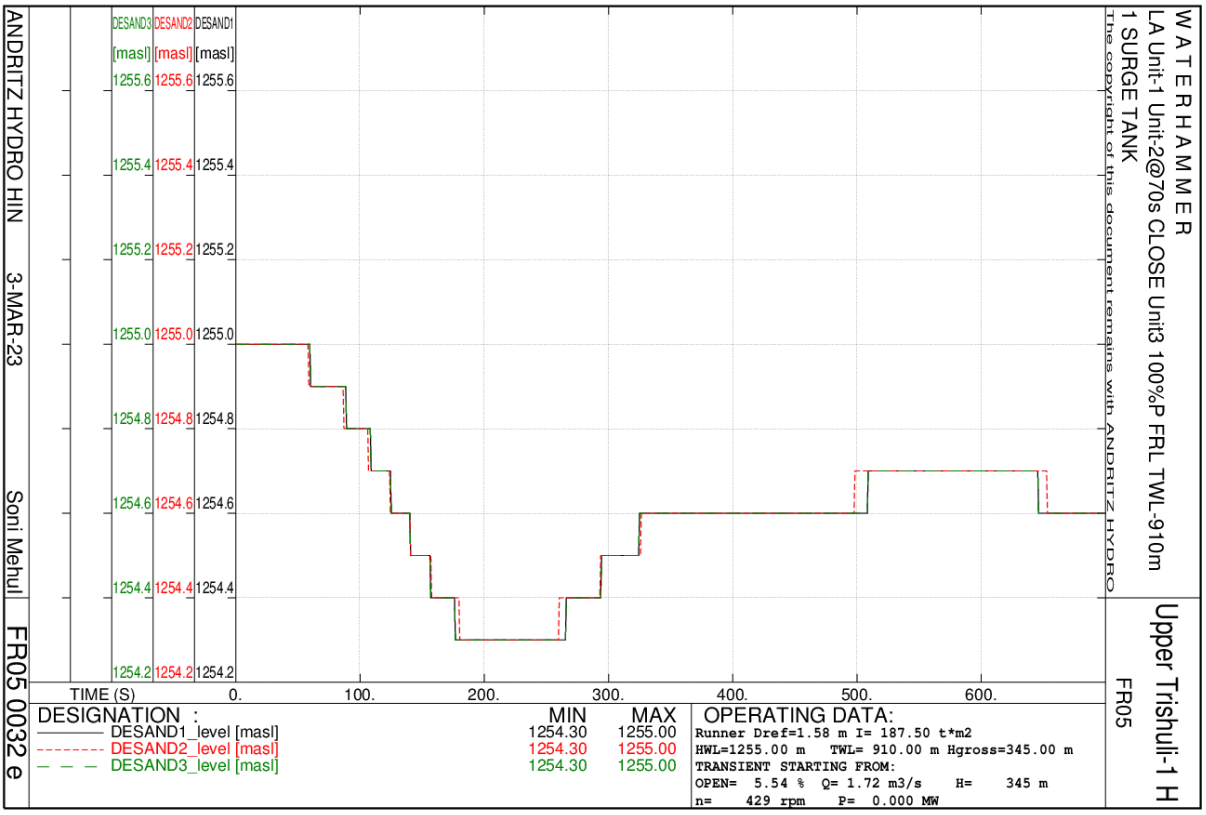
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0032 d
Upper Trishuli-1 H
FR05
DTSSHAF [masl] 914. 913. 912. 911. 910. 909. 908. 907.
DTSSHAF [masl] 914. 913. 912. 911. 910. 909. 908. 907.
DTSSHAF [masl] 914. 913. 912. 911. 910. 909. 908. 907.
SSHAFT_ [masl] 1265. 1260. 1255. 1250. 1245. 1240. 1235. 1230.
TIME (S) 0. 100. 200. 300. 400. 500. 600.
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1239.20 1255.30
DTSSHAFT U1_level [masl] 908.22 912.40
DTSSHAFT U2_level [masl] 908.22 912.40
DTSSHAFT U3_level [masl] 908.28 912.46
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m
1 SURGE TANK
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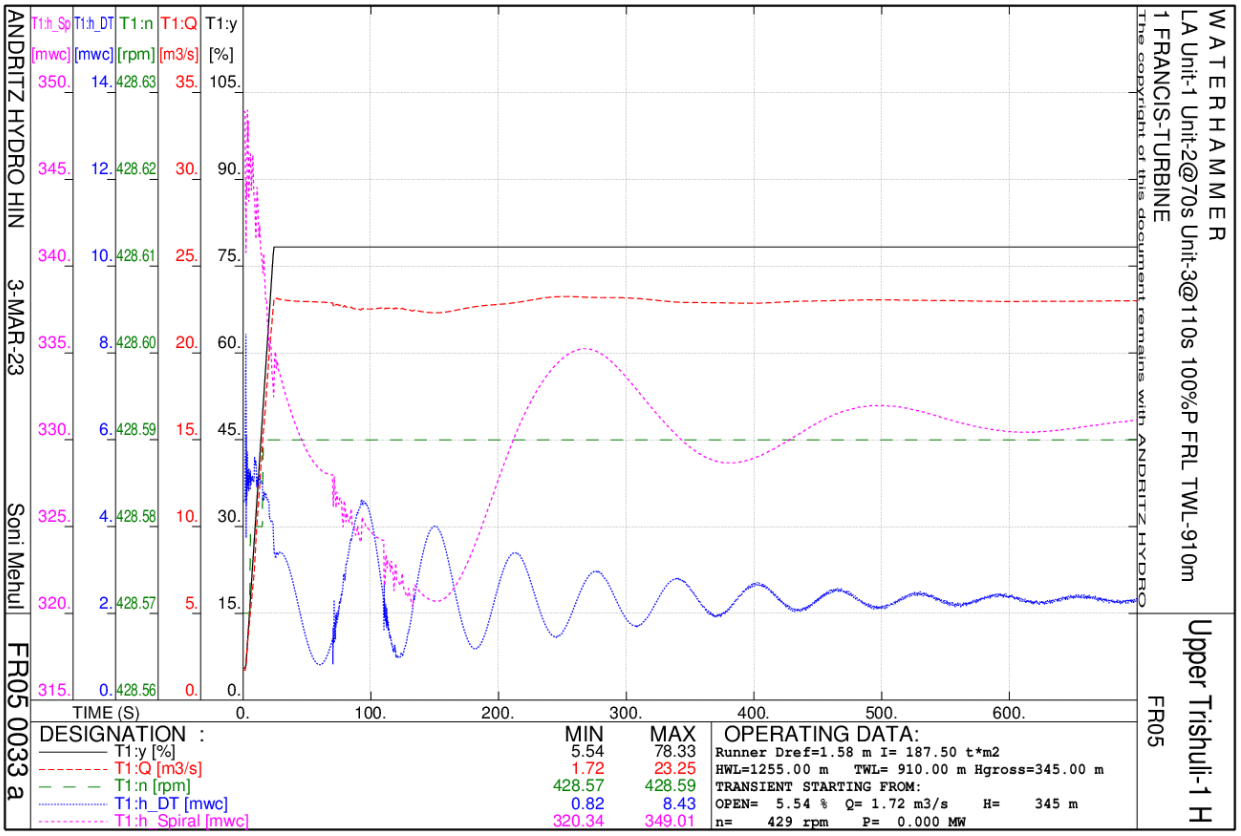
3-MAR-23
Soni Mehul
FR05 0032 e
Upper Trishuli-1 H
FR05
DESAND3 [masl] 1255.6 1255.4 1255.2 1255.0 1254.8 1254.6 1254.4 1254.2
DESAND2 [masl] 1255.6 1255.4 1255.2 1255.0 1254.8 1254.6 1254.4 1254.2
DESAND1 [masl] 1255.6 1255.4 1255.2 1255.0 1254.8 1254.6 1254.4 1254.2
TIME (S) 0. 100. 200. 300. 400. 500. 600.
DESIGNATION : MIN MAX
DESAND1_level [masl] 1254.30 1255.00
DESAND2_level [masl] 1254.30 1255.00
DESAND3_level [masl] 1254.30 1255.00
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW

FR05 0032 LA Unit-1 Unit-2@70s CLOSE Unit3 100%P FRL TWL-910m


WATERHAMMER
LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m
1 FRANCIS-TURBINE
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Upper Trishuli-1 H
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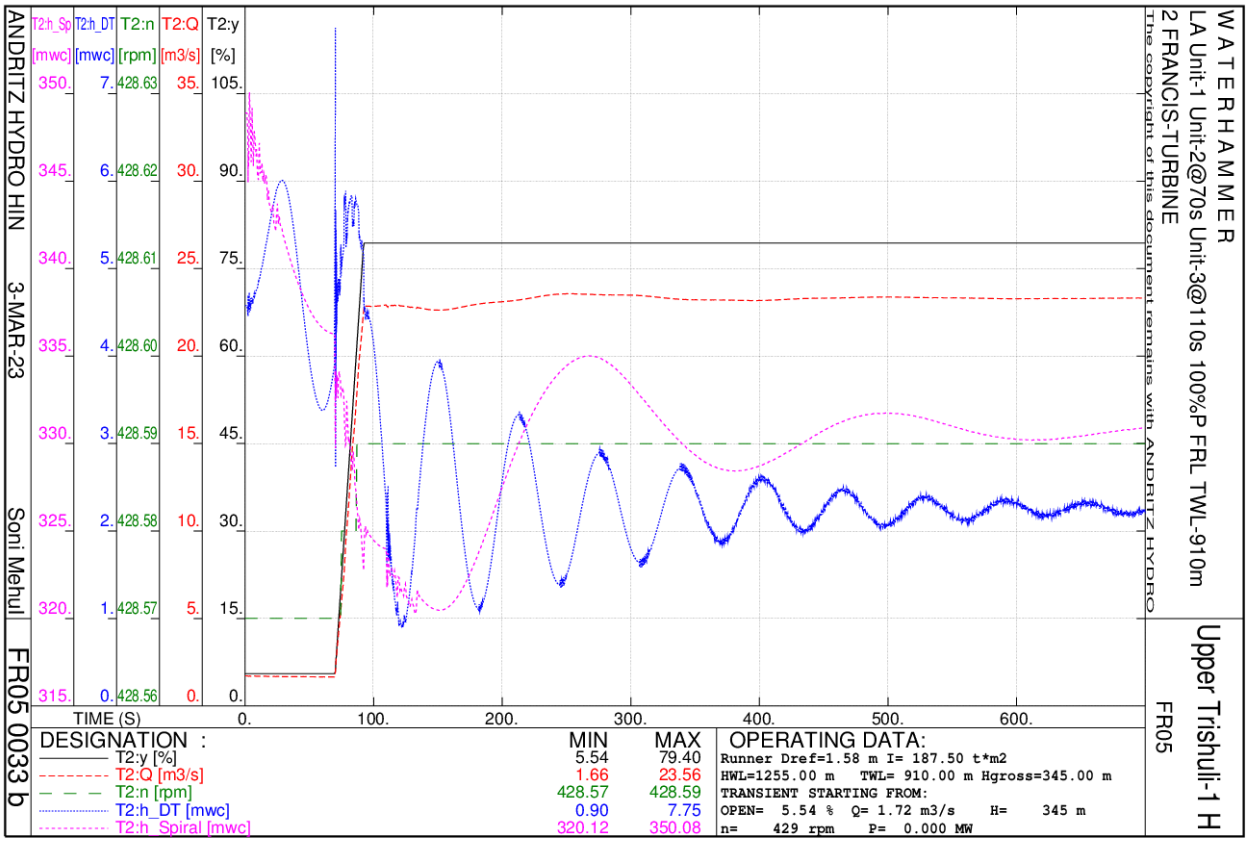
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0033 a
T1:h_Sp [mwc]
T1:h_DT [mwc]
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
TIME (S)
DESIGNATION :
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
T1:h_DT [mwc]
T1:h_Spiral [mwc]
MIN
MAX
5.54 78.33
1.72 23.25
428.57 428.59
0.82 8.43
320.34 349.01
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m
2 FRANCIS-TURBINE
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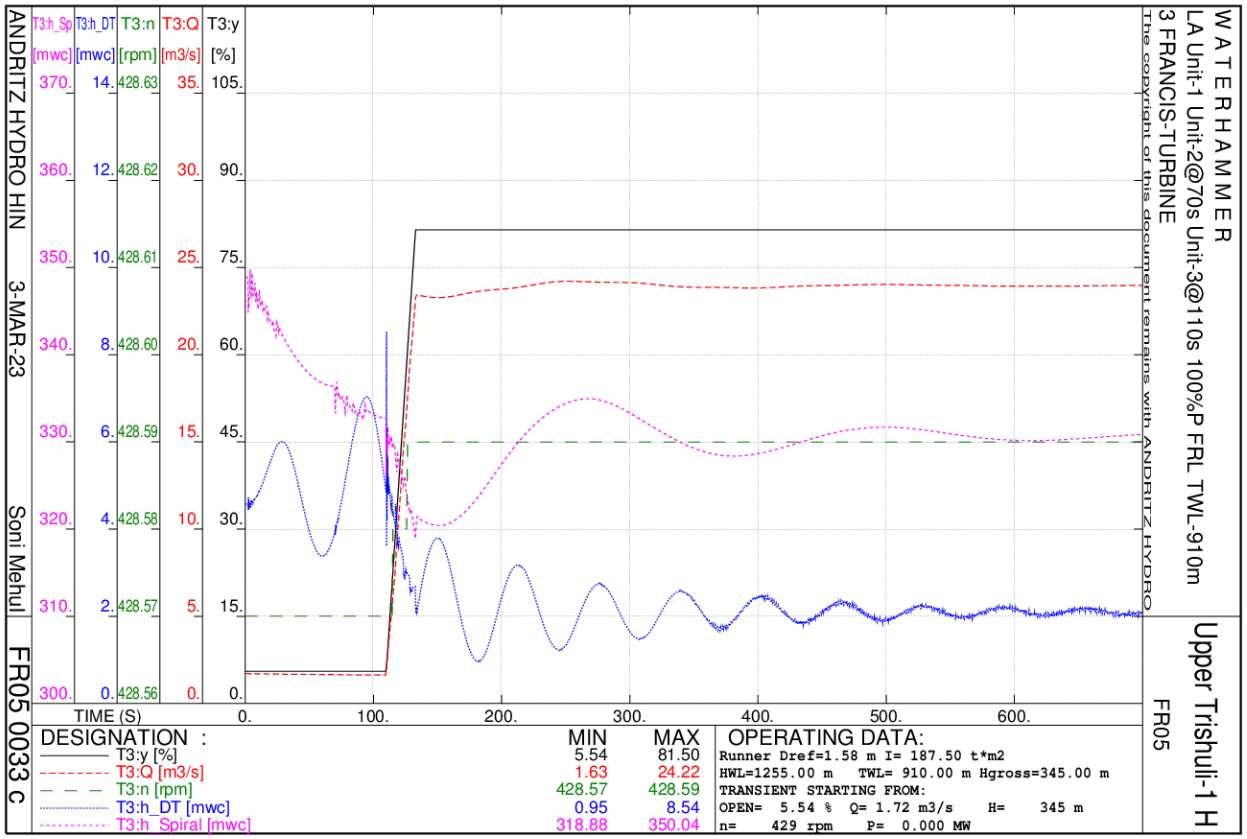
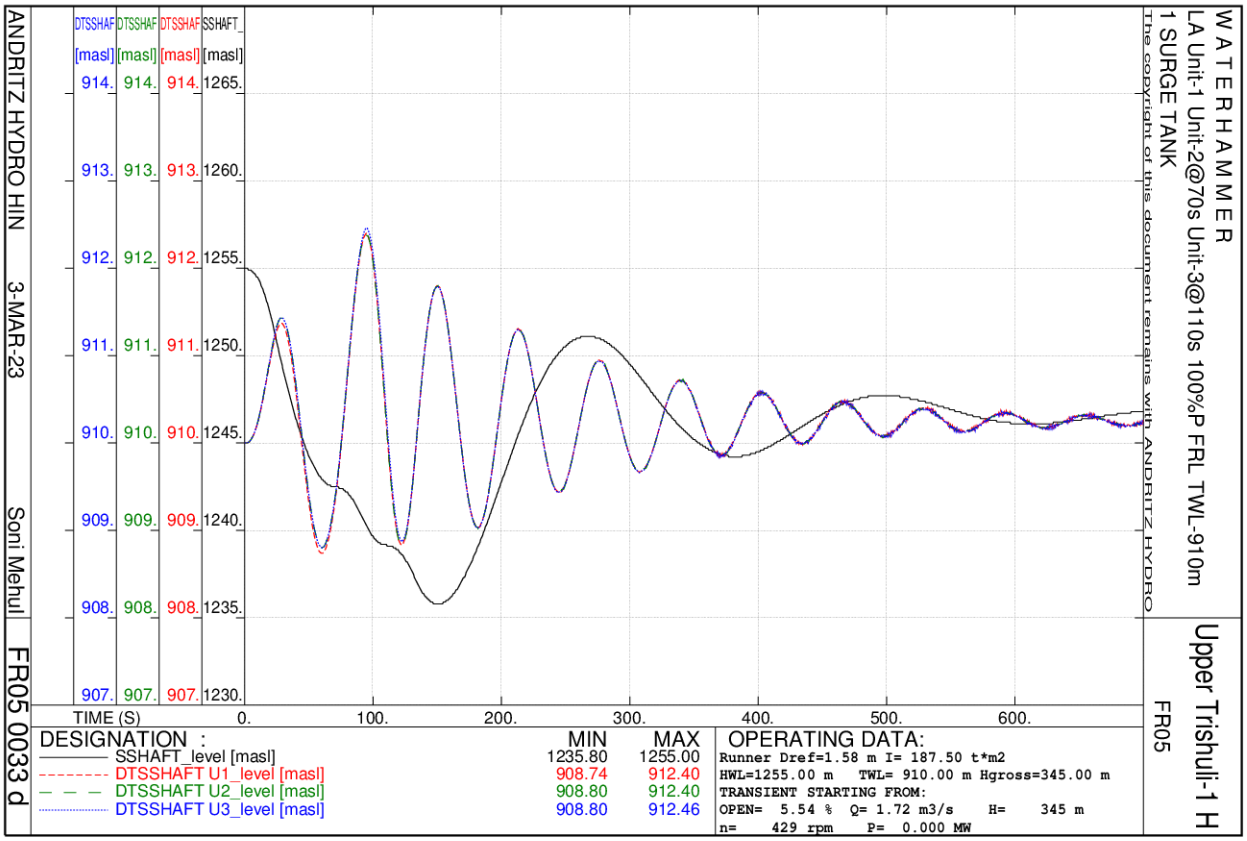
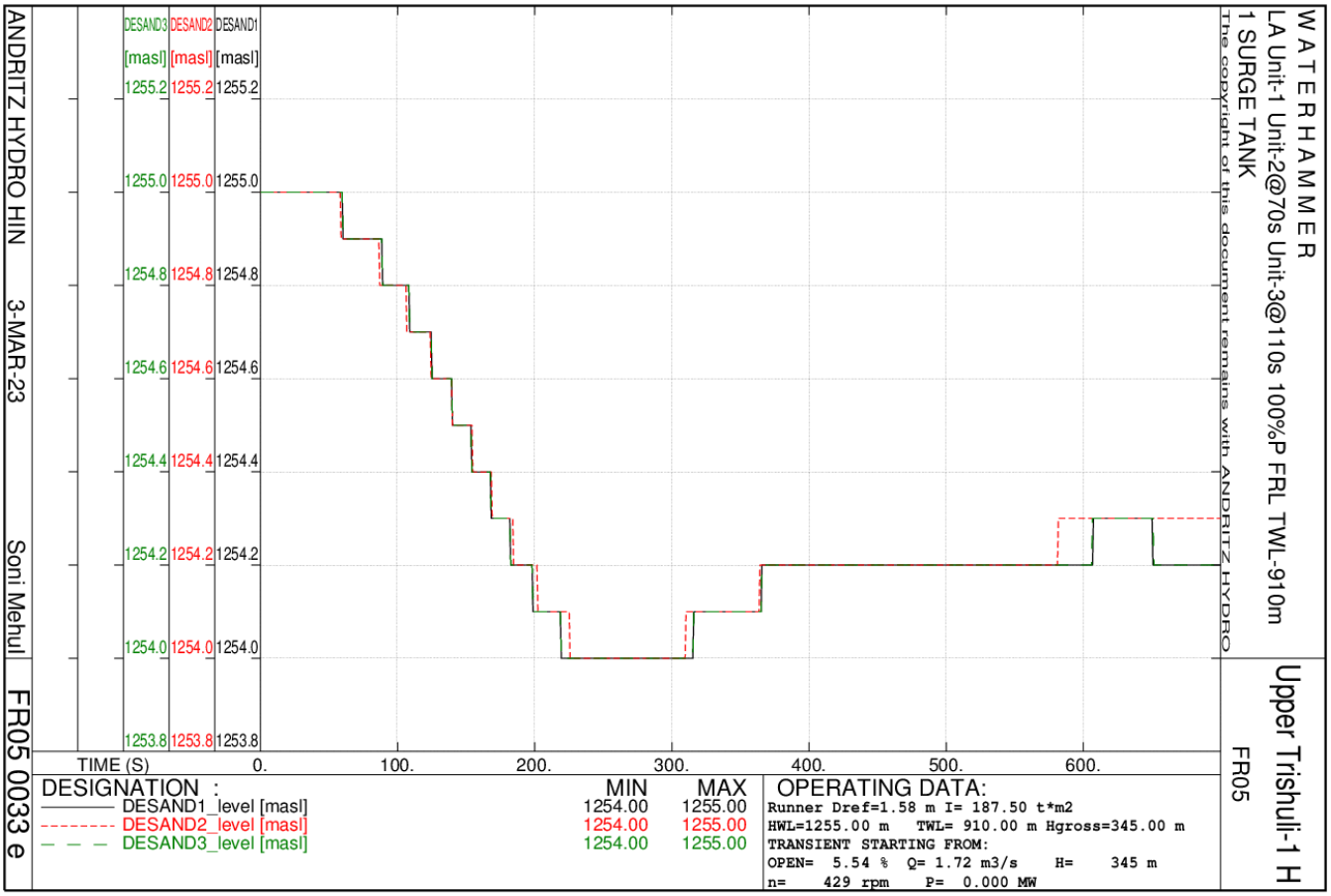
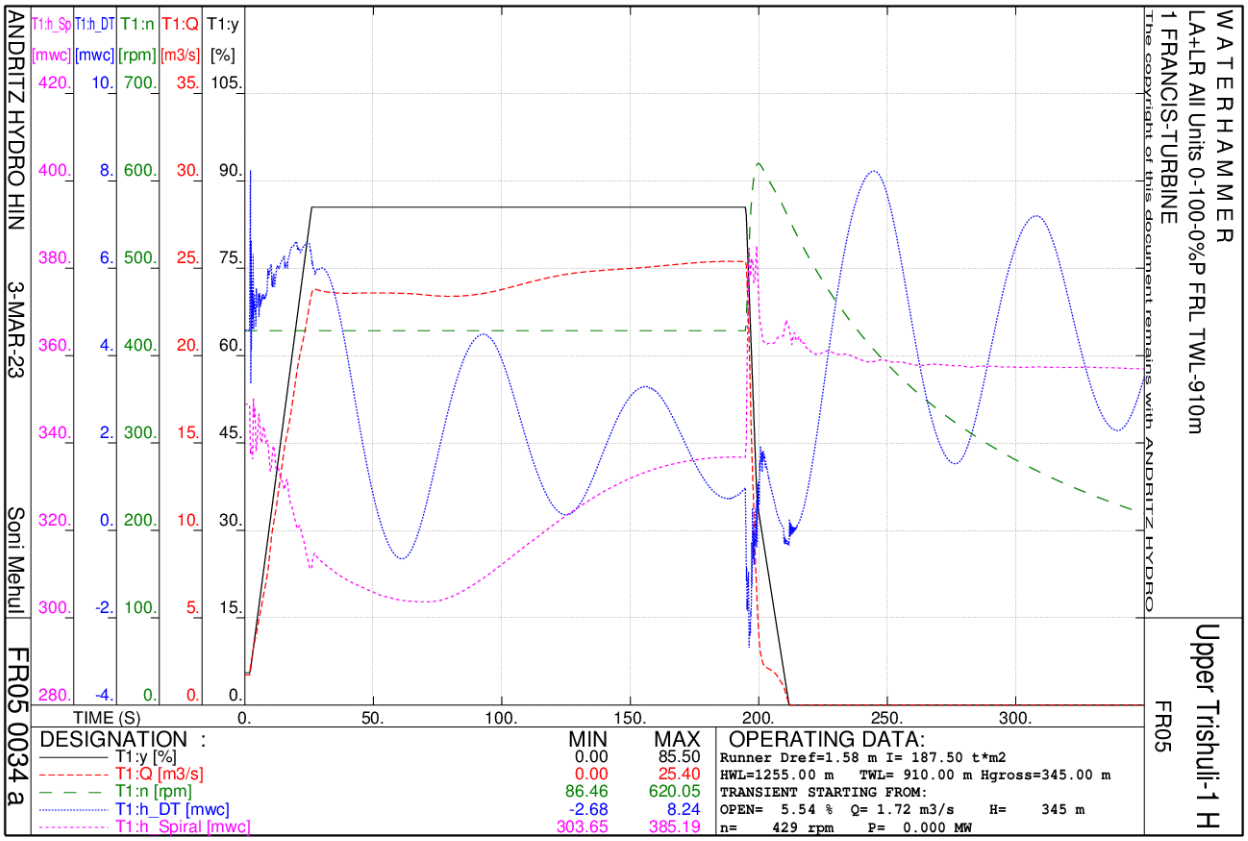
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0033 b
T2:h_Sp [mwc]
T2:h_DT [mwc]
T2:n [rpm]
T2:Q [m3/s]
T2:y [%]
TIME (S)
DESIGNATION :
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
T2:h_DT [mwc]
T2:h_Spiral [mwc]
MIN
MAX
5.54 79.40
1.66 23.56
428.57 428.59
0.90 7.75
320.12 350.08
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m
3 FRANCIS-TURBINE
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0033 c
T3:h_Sp [mwc] T3:h_DT [mwc] T3:n [rpm] T3:Q [m3/s] T3:y [%]
TIME (S)
DESIGNATION : MIN MAX
T3:y [%] 5.54 81.50
T3:Q [m3/s] 1.63 24.22
T3:n [rpm] 428.57 428.59
T3:h_DT [mwc] 0.95 8.54
T3:h_Spiral [mwc] 318.88 350.04
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m
1 SURGE TANK
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0033 d
DTSSHAF [masl] DTSSHAF [masl] DTSSHAF [masl] SSHAFT_ [masl]
TIME (S)
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1235.80 1255.00
DTSSHAFT U1_level [masl] 908.74 912.40
DTSSHAFT U2_level [masl] 908.80 912.40
DTSSHAFT U3_level [masl] 908.80 912.46
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW



FR05 0033 LA Unit-1 Unit-2@70s Unit-3@110s 100%P FRL TWL-910m


WATERHAMMER
LA+LR All Units 0-100-0%P FRL TWL-910m
1 FRANCIS-TURBINE
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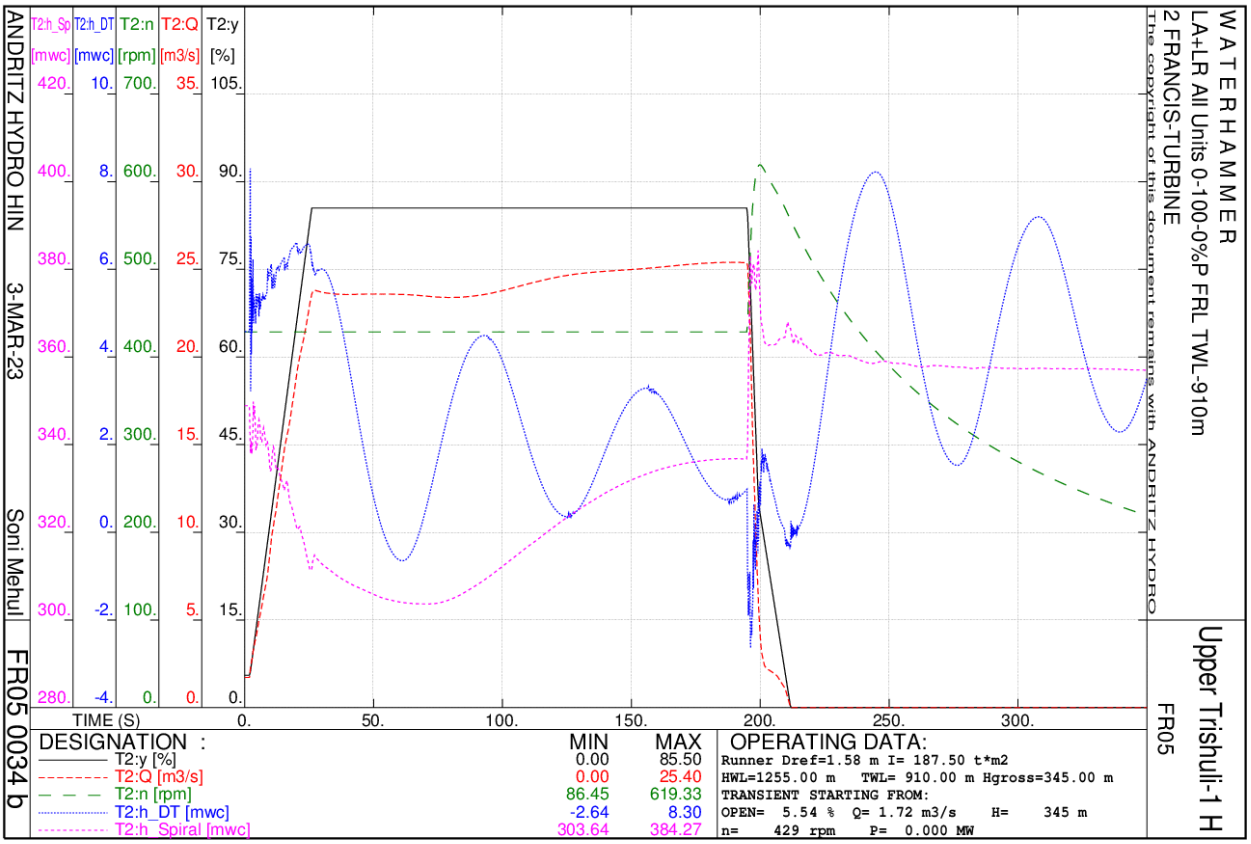
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0034 a
Upper Trishuli-1 H
FR05
T1:h_Sp [mwc] T1:h_DT [mwc] T1:n [rpm] T1:Q [m3/s] T1:y [%]
TIME (S)
DESIGNATION : MIN MAX
T1:y [%] 0.00 85.50
T1:Q [m3/s] 0.00 25.40
T1:n [rpm] 86.46 620.05
T1:h_DT [mwc] -2.68 8.24
T1:h_Spiral [mwc] 303.65 385.19
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA+LR All Units 0-100-0%P FRL TWL-910m
2 FRANCIS-TURBINE
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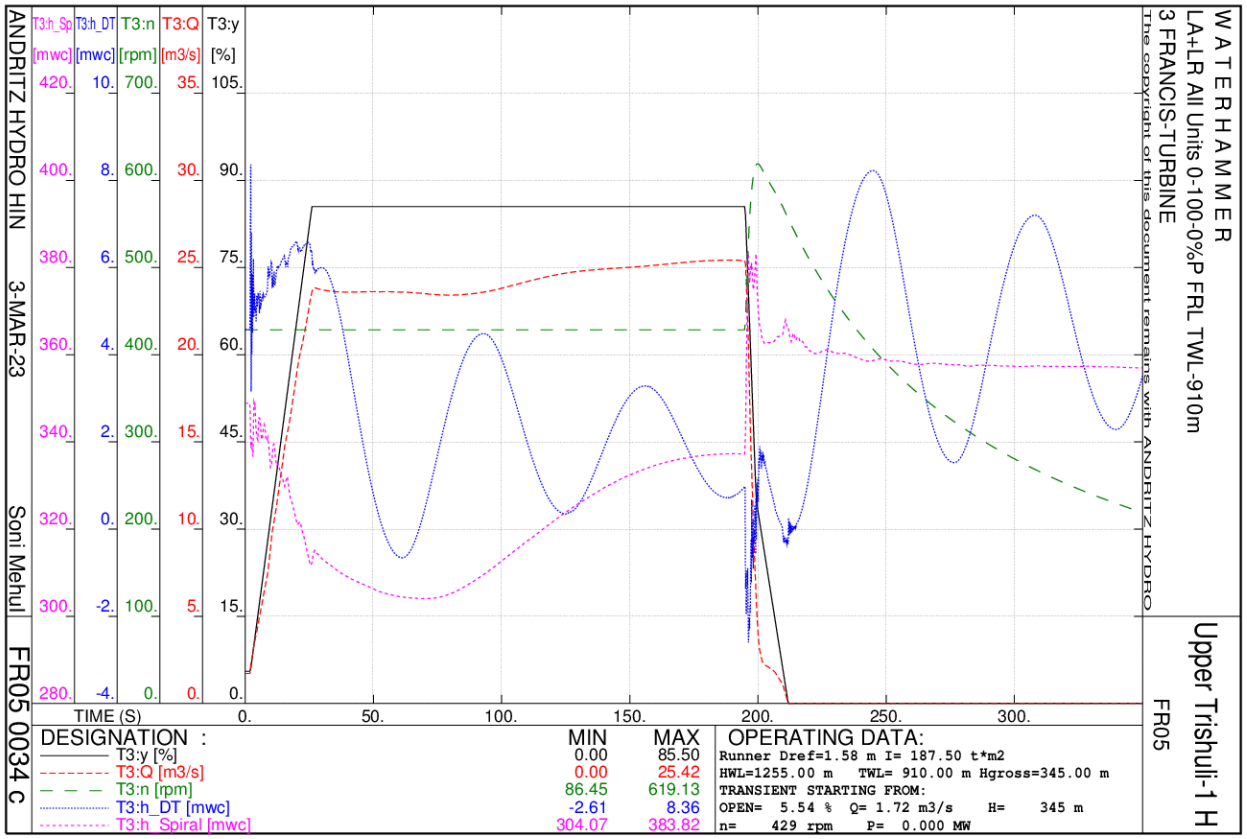
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0034 b
Upper Trishuli-1 H
FR05
T2:h_Sp [mwc] T2:h_DT [mwc] T2:n [rpm] T2:Q [m3/s] T2:y [%]
TIME (S)
DESIGNATION : MIN MAX
T2:y [%] 0.00 85.50
T2:Q [m3/s] 0.00 25.40
T2:n [rpm] 86.45 619.33
T2:h_DT [mwc] -2.64 8.30
T2:h_Spiral [mwc] 303.64 384.27
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA+LR All Units 0-100-0%P FRL TWL-910m
3 FRANCIS-TURBINE
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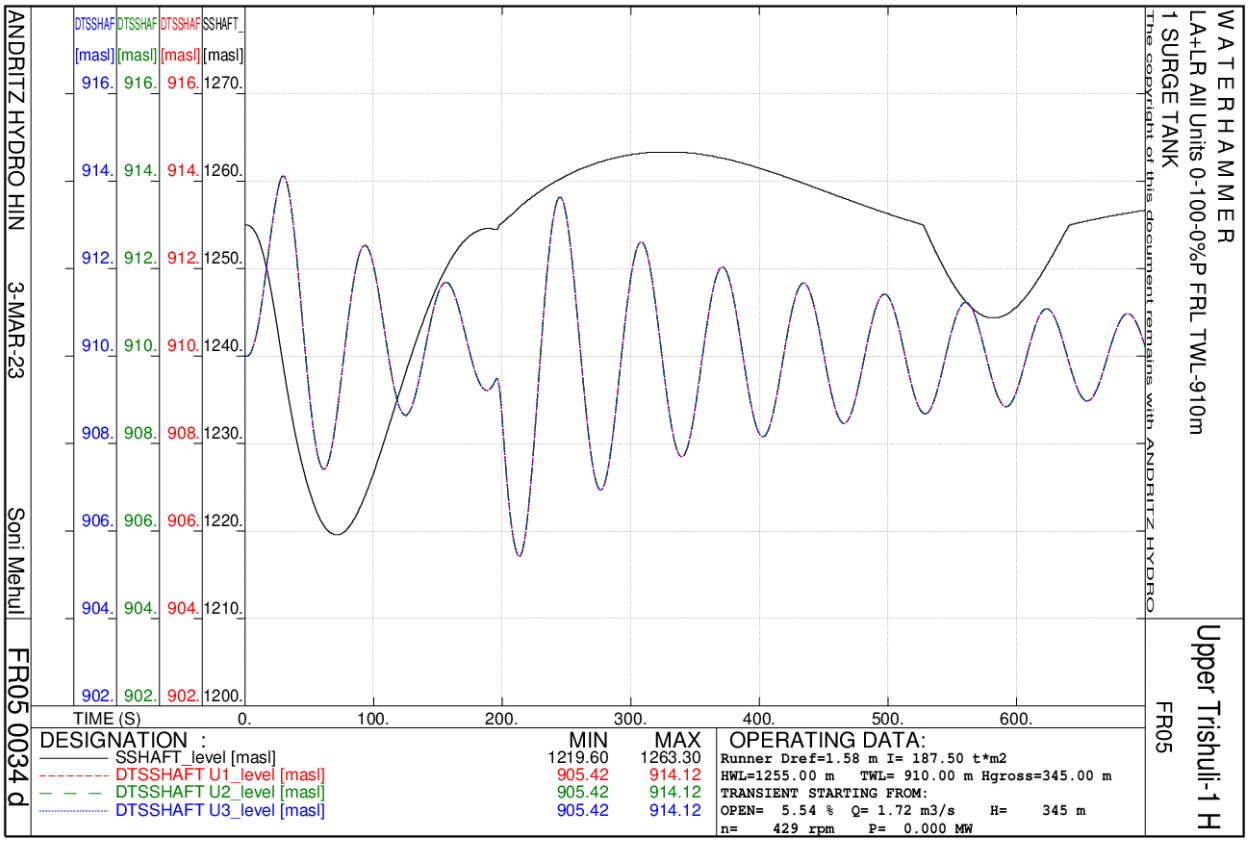
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0034 c
T3:h_Sp [mwc] T3:h_DT [mwc] T3:n [rpm] T3:Q [m3/s] T3:y [%]
TIME (S)
DESIGNATION : MIN MAX
T3:y [%] 0.00 85.50
T3:Q [m3/s] 0.00 25.42
T3:n [rpm] 86.45 619.13
T3:h_DT [mwc] -2.61 8.36
T3:h_Spiral [mwc] 304.07 383.82
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA+LR All Units 0-100-0%P FRL TWL-910m
1 SURGE TANK
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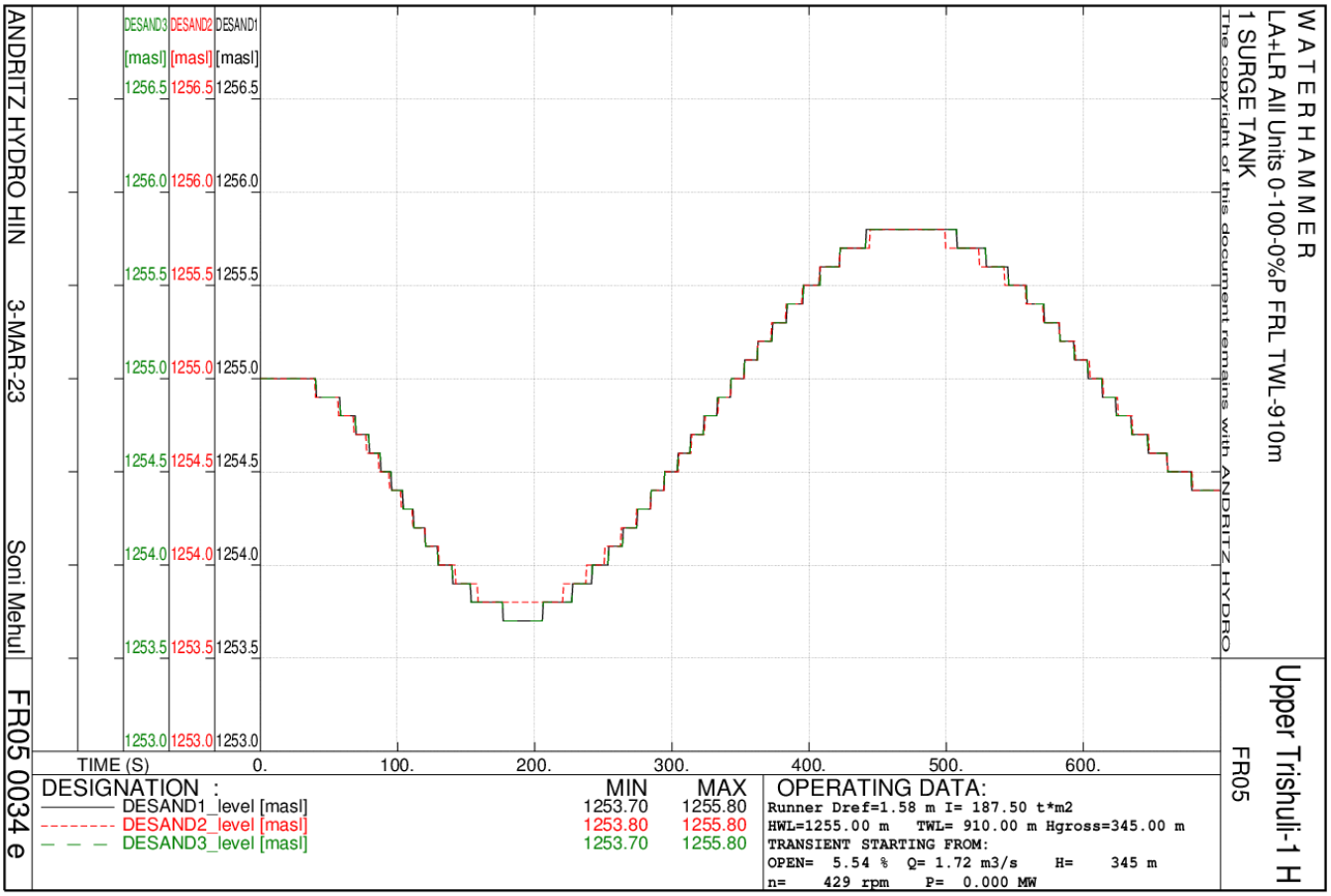
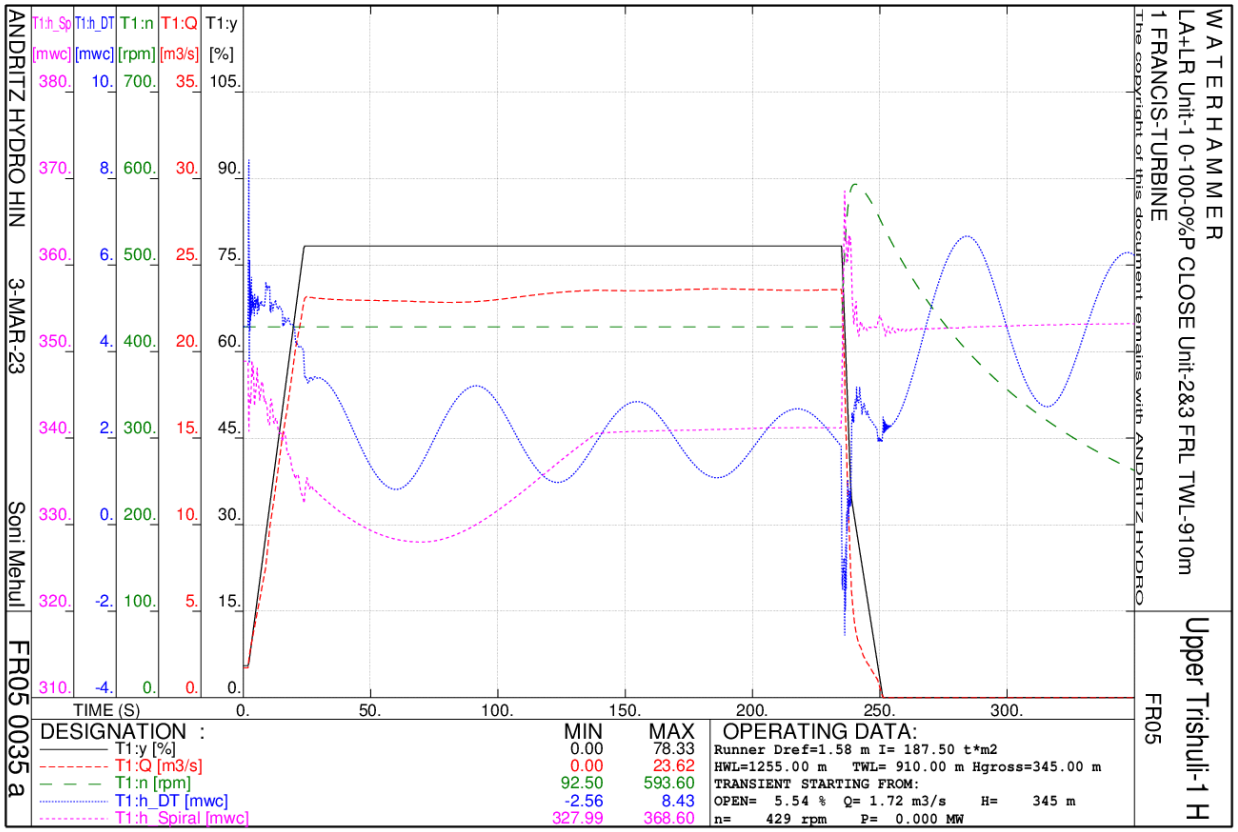
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0034 d
DTSSHAF [masl] DTSSHAF [masl] DTSSHAF [masl] SSHAFT_ [masl]
TIME (S)
DESIGNATION : MIN MAX
SSHAFT_level [masl] 1219.60 1263.30
DTSSHAFT U1_level [masl] 905.42 914.12
DTSSHAFT U2_level [masl] 905.42 914.12
DTSSHAFT U3_level [masl] 905.42 914.12
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW



FR05 0034 LA+LR All Units 0-100-0%P FRL TWL-910m


WATERHAMMER
LA+LR Unit-1 0-100-0%P CLOSE Unit-2&3 FRL TWL-910m
1 FRANCIS-TURBINE
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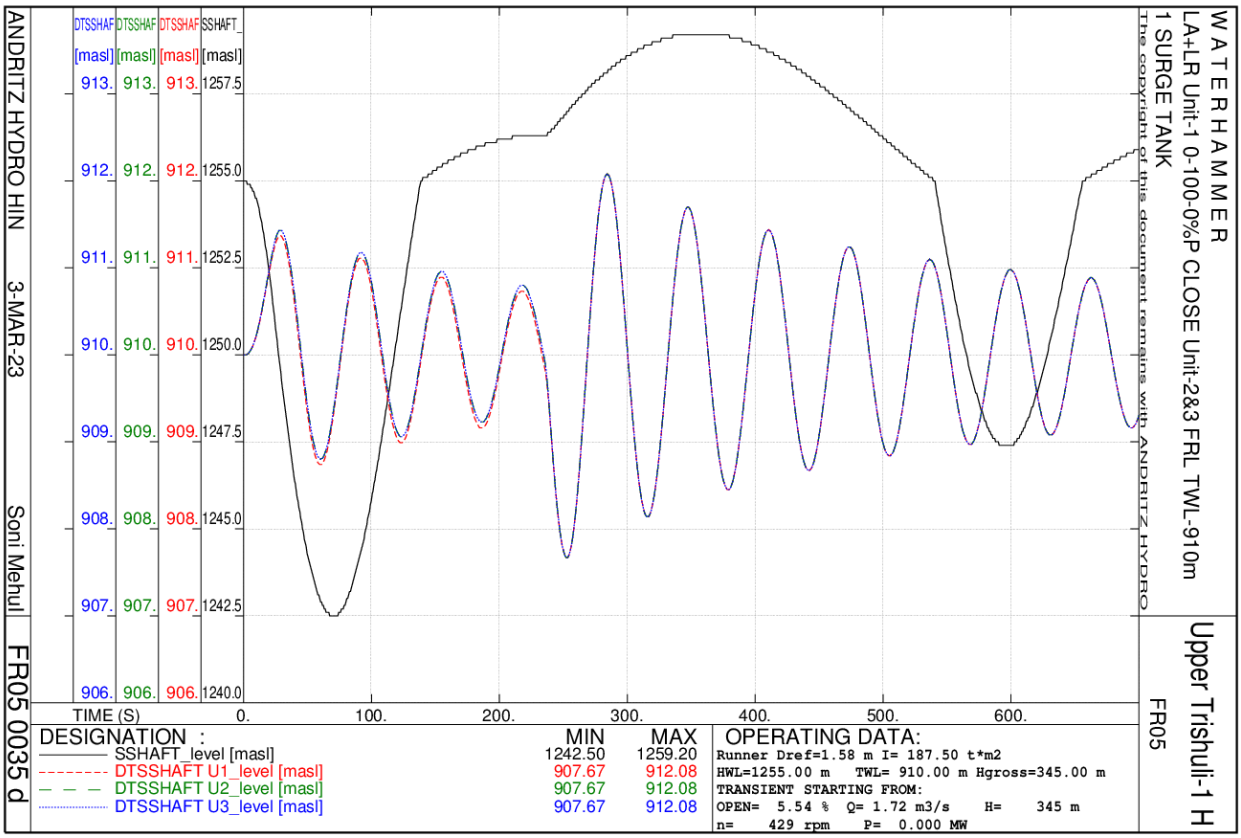
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0035 a
Upper Trishuli-1 H
FR05
T1:h_Sp [mwc]
T1:h_DT [mwc]
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
TIME (S)
DESIGNATION :
T1:y [%] MIN 0.00 MAX 78.33
T1:Q [m3/s] MIN 0.00 MAX 23.62
T1:n [rpm] MIN 92.50 MAX 593.60
T1:h_DT [mwc] MIN -2.56 MAX 8.43
T1:h_Spiral [mwc] MIN 327.99 MAX 368.60
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA+LR Unit-1 0-100-0%P CLOSE Unit-2&3 FRL TWL-910m
1 SURGE TANK
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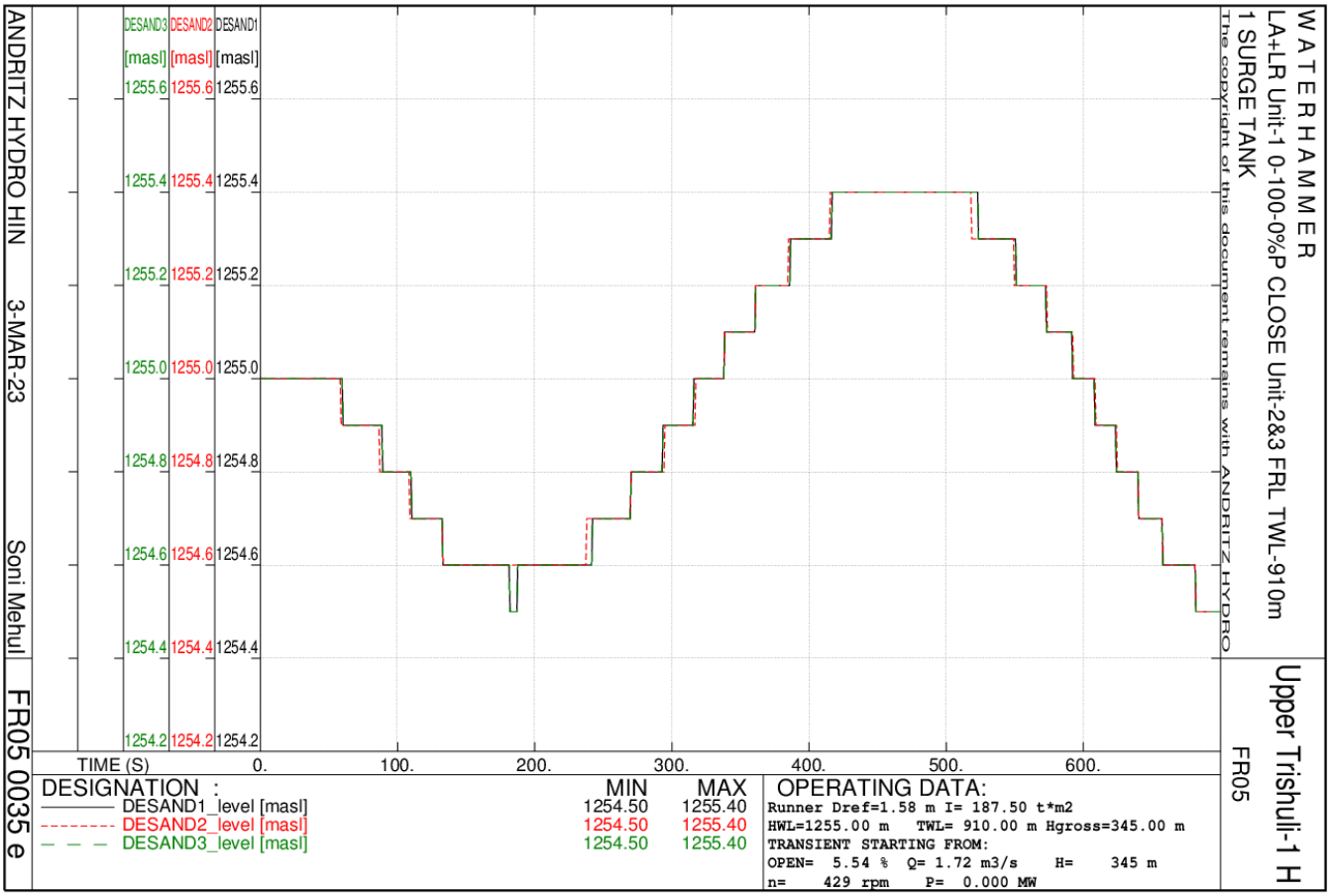
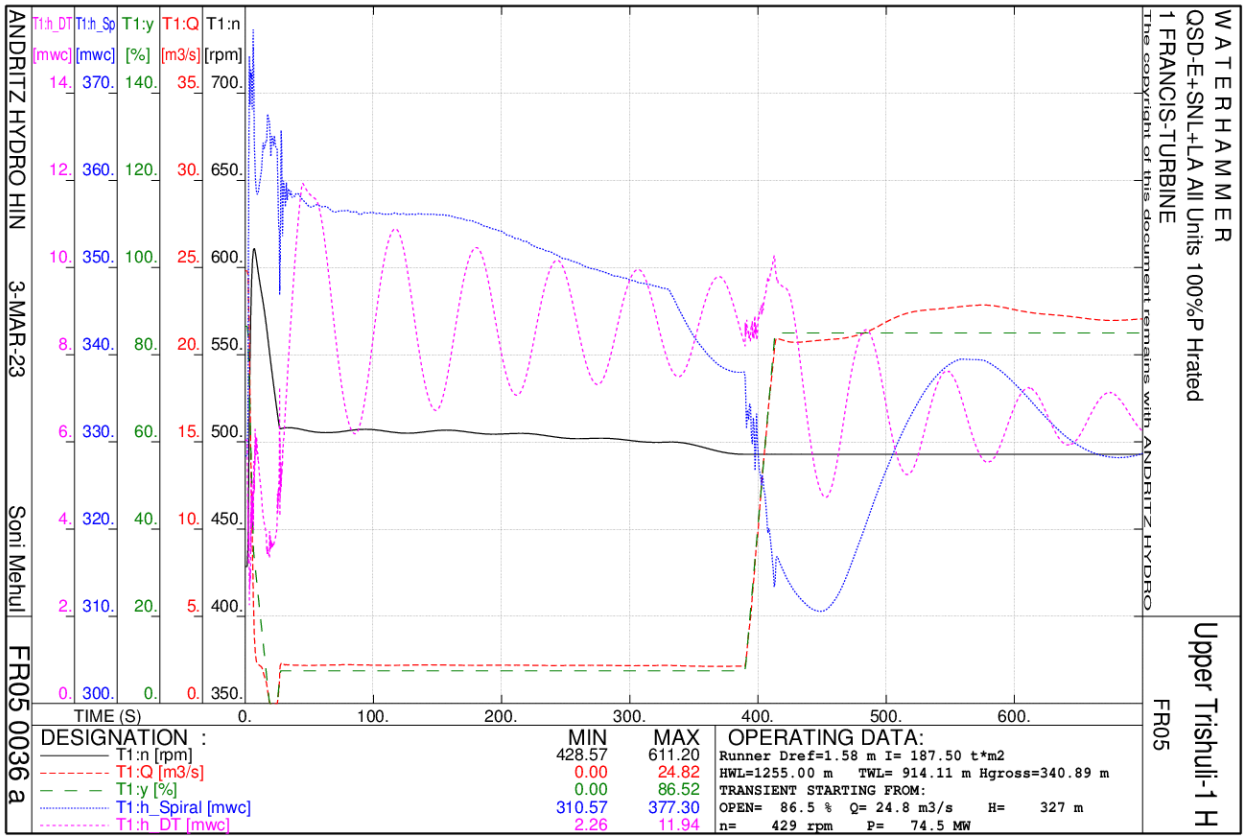
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0035 d
Upper Trishuli-1 H
FR05
DTSSHAFT_level [masl]
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1242.50 MAX 1259.20
DTSSHAFT U1_level [masl] MIN 907.67 MAX 912.08
DTSSHAFT U2_level [masl] MIN 907.67 MAX 912.08
DTSSHAFT U3_level [masl] MIN 907.67 MAX 912.08
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 910.00 m Hgross=345.00 m
TRANSIENT STARTING FROM:
OPEN= 5.54 % Q= 1.72 m3/s H= 345 m
n= 429 rpm P= 0.000 MW



FR05 0035 LA+LR Unit-1 0-100-0%P CLOSE Unit-2&3 FRL TWL-910m


WATERHAMMER
QSD-E+SNL+LA All Units 100%P Hrated
1 FRANCIS-TURBINE
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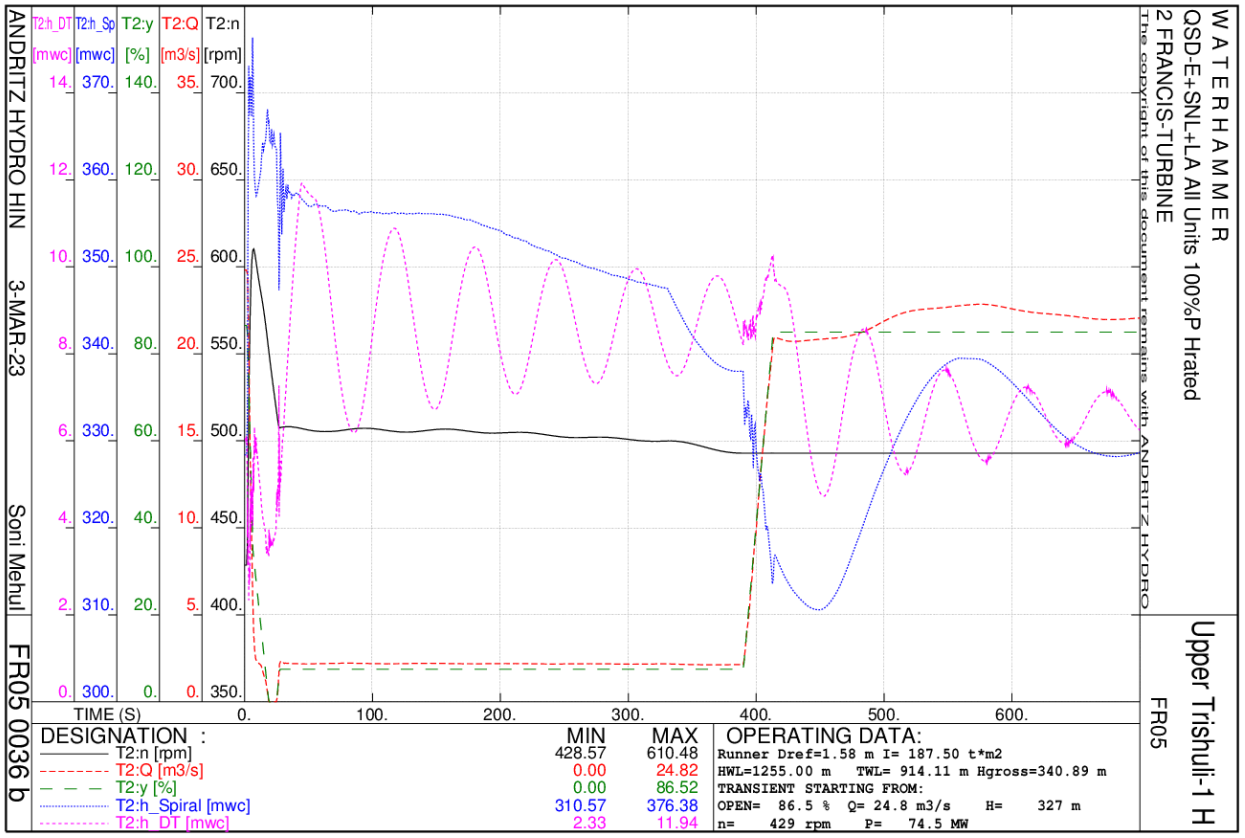
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0036 a
T1:h_DT [mwc]
T1:h_Sp [mwc]
T1:y [%]
T1:Q [m3/s]
T1:n [rpm]
TIME (S)
DESIGNATION :
T1:n [rpm] MIN 428.57 MAX 611.20
T1:Q [m3/s] 0.00 24.82
T1:y [%] 0.00 86.52
T1:h_Spiral [mwc] 310.57 377.30
T1:h_DT [mwc] 2.26 11.94
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E+SNL+LA All Units 100%P Hrated
2 FRANCIS-TURBINE
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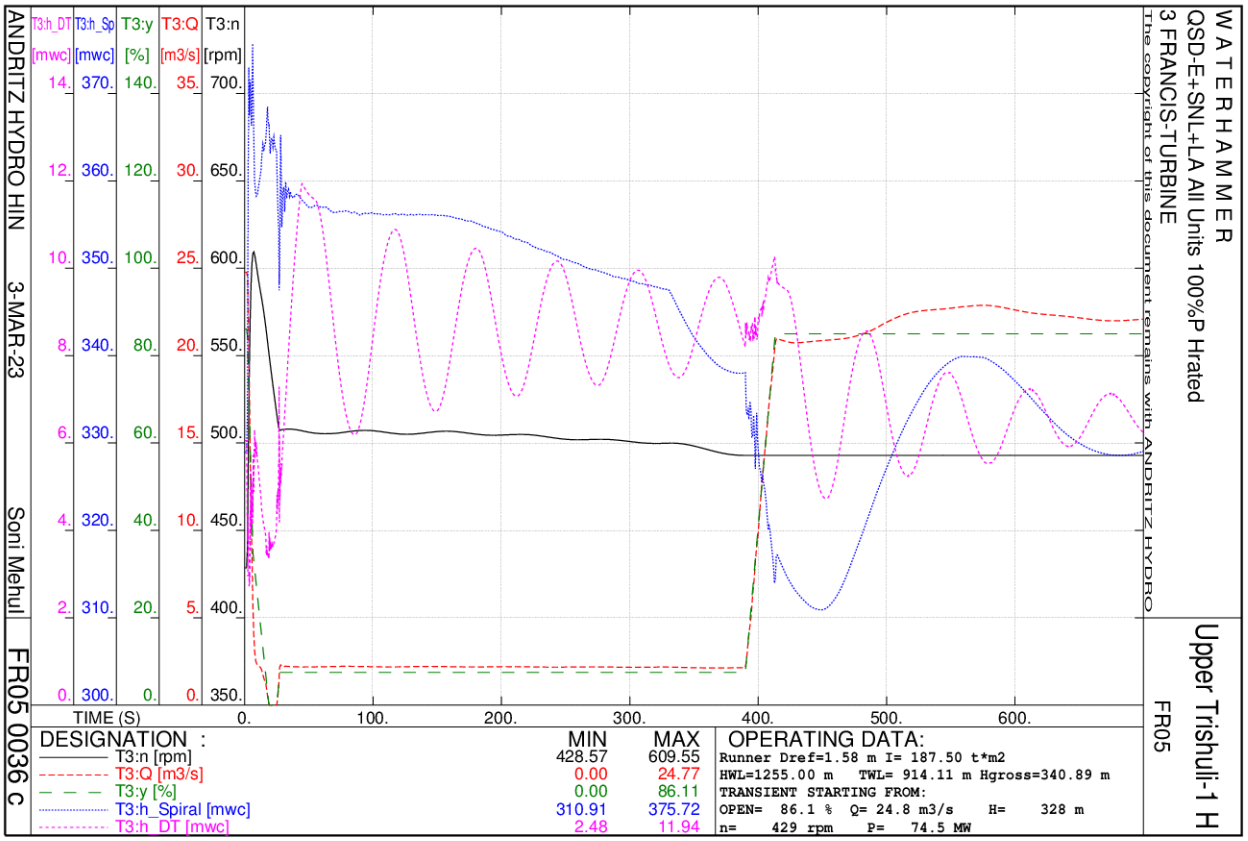
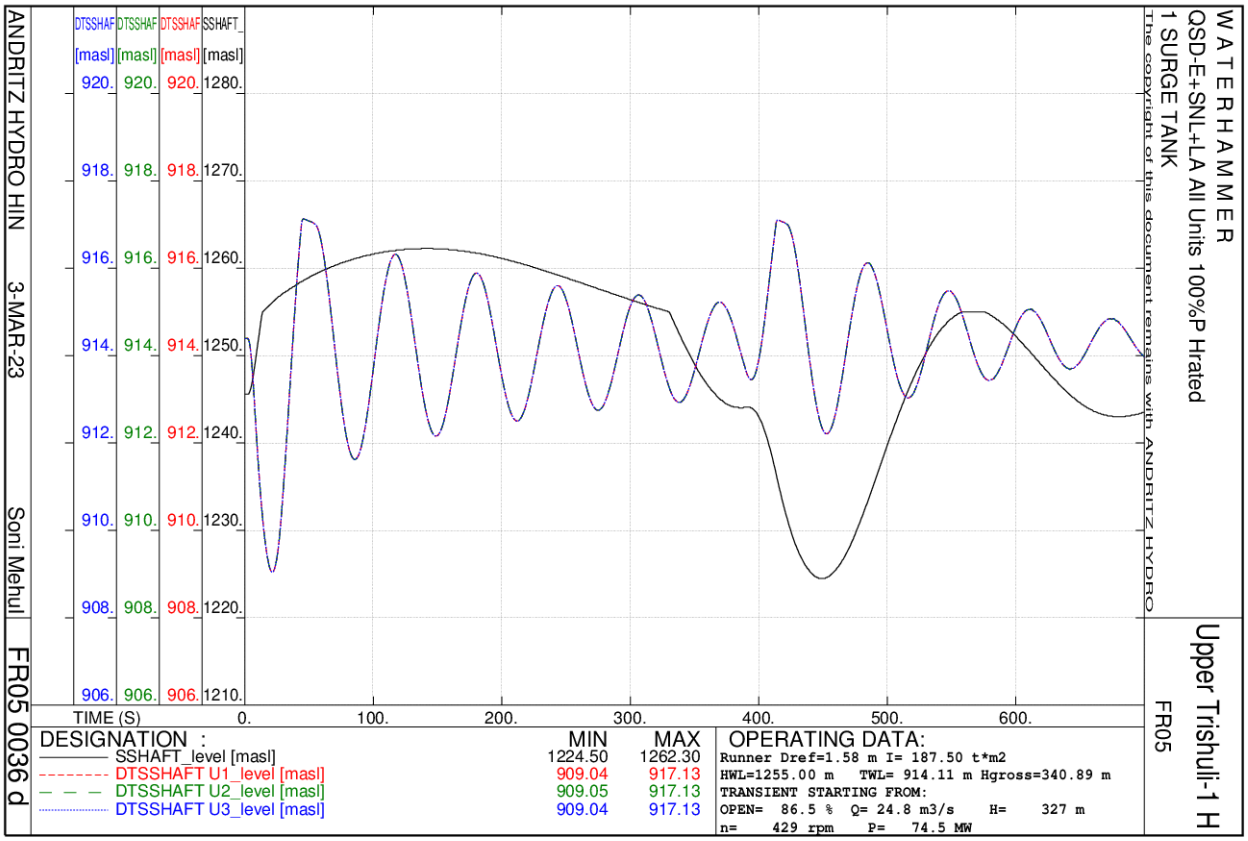
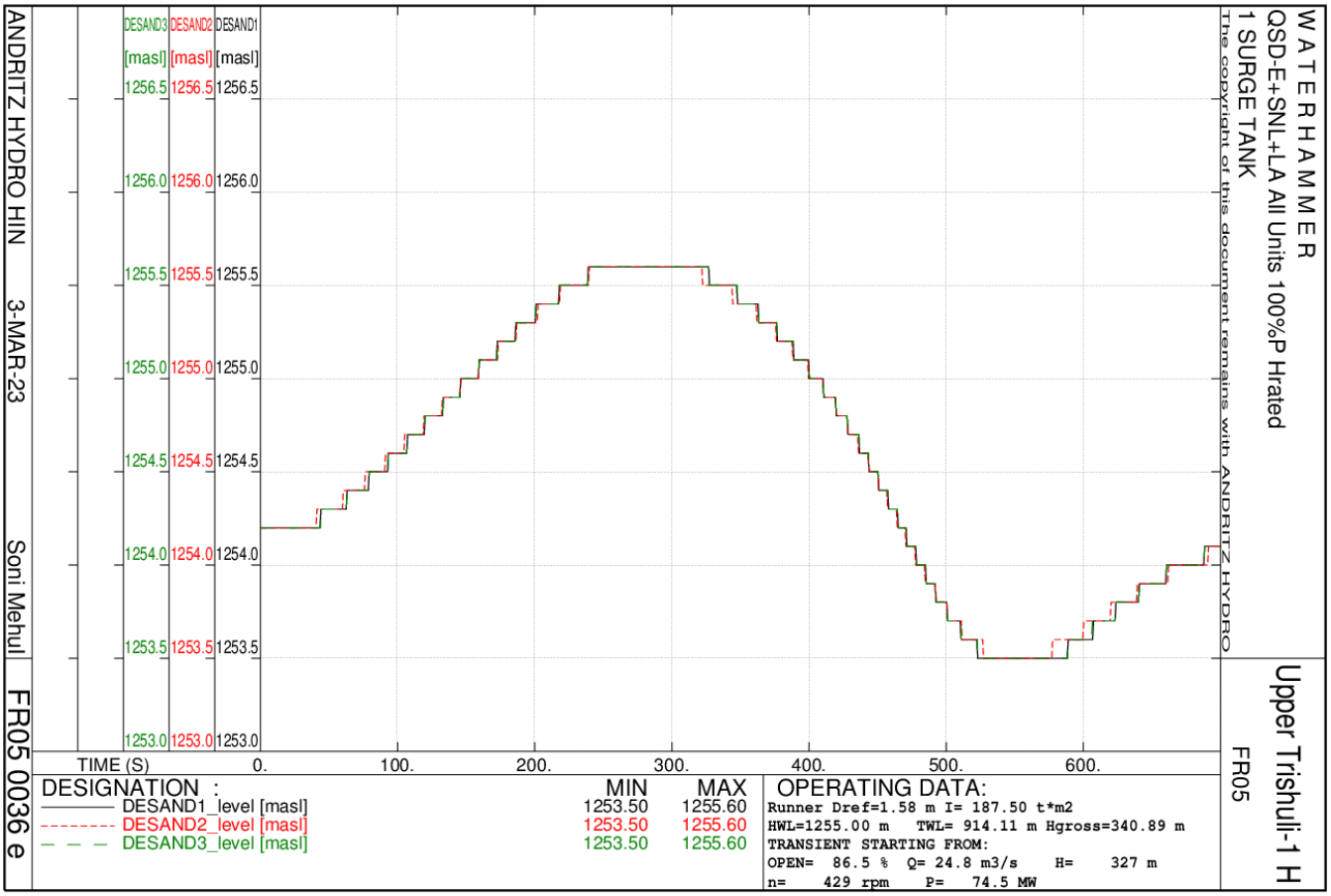
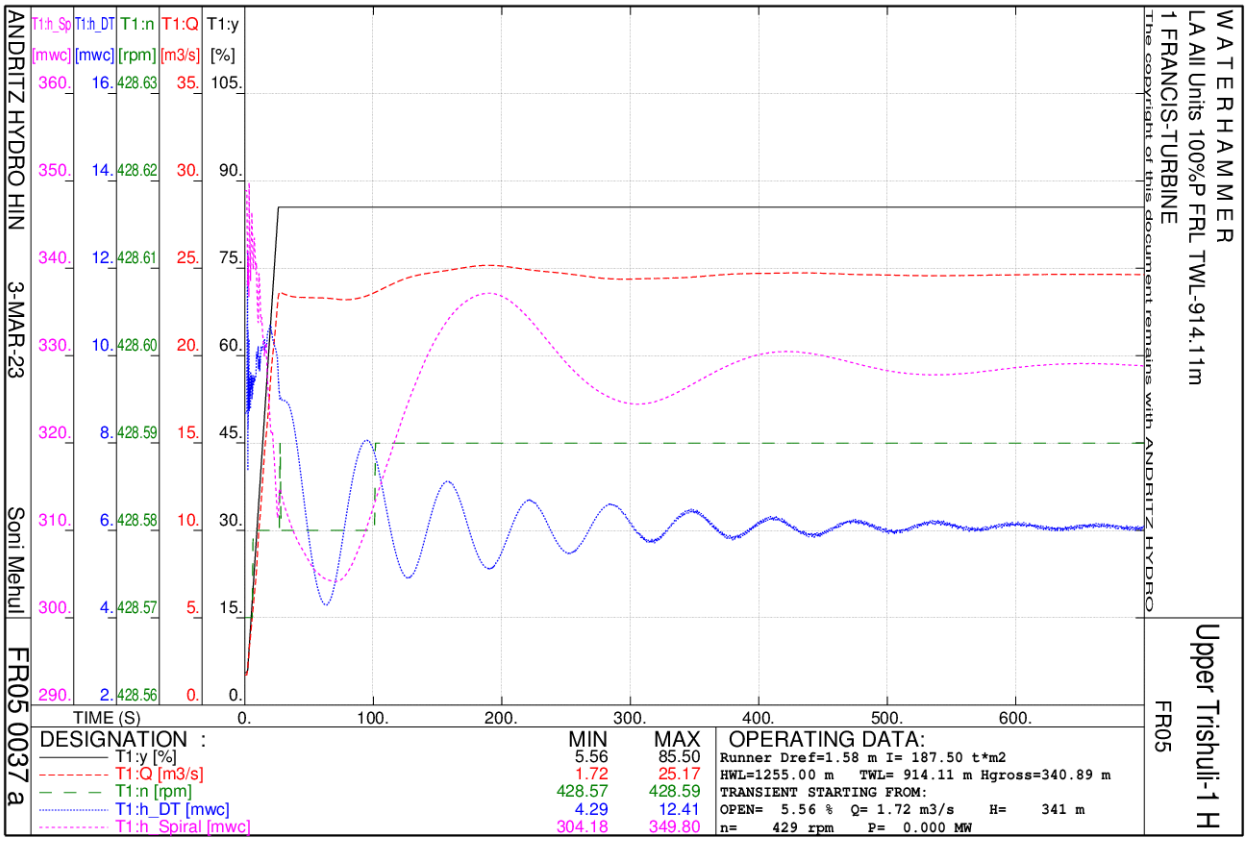
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0036 b
T2:h_DT [mwc]
T2:h_Sp [mwc]
T2:y [%]
T2:Q [m3/s]
T2:n [rpm]
TIME (S)
DESIGNATION :
T2:n [rpm] MIN 428.57 MAX 610.48
T2:Q [m3/s] 0.00 24.82
T2:y [%] 0.00 86.52
T2:h_Spiral [mwc] 310.57 376.38
T2:h_DT [mwc] 2.33 11.94
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E+SNL+LA All Units 100%P Hrated
3 FRANCIS-TURBINE
The copyright of this document remains with ANDRITZ HYDRO
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0036 c
T3:h_DT [mwc]
T3:h_Sp [mwc]
T3:y [%]
T3:Q [m3/s]
T3:n [rpm]
TIME (S)
DESIGNATION :
T3:n [rpm] MIN 428.57 MAX 609.55
T3:Q [m3/s] 0.00 24.77
T3:y [%] 0.00 86.11
T3:h_Spiral [mwc] 310.91 375.72
T3:h_DT [mwc] 2.48 11.94
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.1 % Q= 24.8 m3/s H= 328 m
n= 429 rpm P= 74.5 MW


WATERHAMMER
QSD-E+SNL+LA All Units 100%P Hrated
1 SURGE TANK
The copyright of this document remains with ANDRITZ HYDRO
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0036 d
DTSSHAFT U1_level [masl]
DTSSHAFT U2_level [masl]
DTSSHAFT U3_level [masl]
SSHAFT_level [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1224.50 MAX 1262.30
DTSSHAFT U1_level [masl] 909.04 917.13
DTSSHAFT U2_level [masl] 909.05 917.13
DTSSHAFT U3_level [masl] 909.04 917.13
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 86.5 % Q= 24.8 m3/s H= 327 m
n= 429 rpm P= 74.5 MW



FR05 0036 QSD-E+SNL+LA All Units 100%P Hrated


WATERHAMMER
LA All Units 100%P FRL TWL-914.11m
1 FRANCIS-TURBINE
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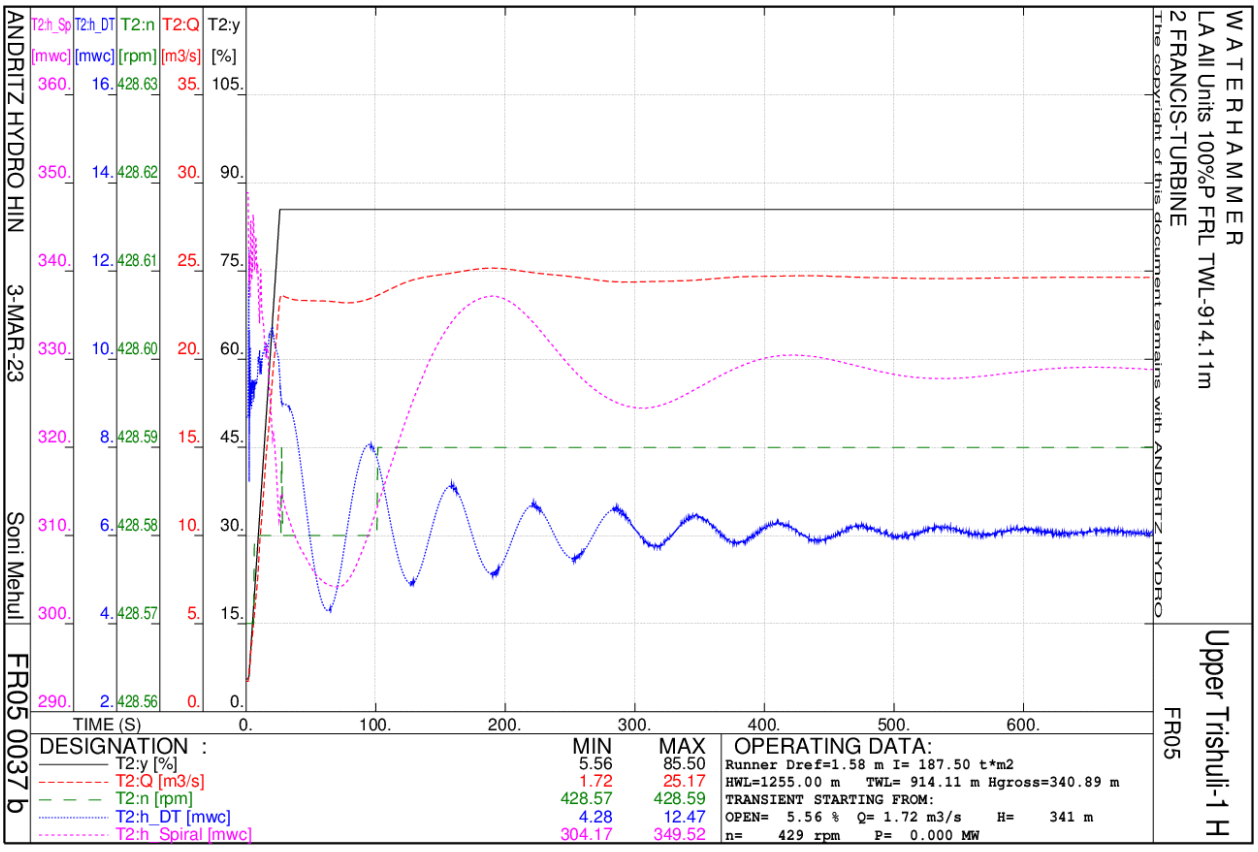
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0037 a
T1:h_Sp [mwc]
T1:h_DT [mwc]
T1:n [rpm]
T1:Q [m3/s]
T1:y [%]
TIME (S)
DESIGNATION :
T1:y [%] MIN 5.56 MAX 85.50
T1:Q [m3/s] 1.72 25.17
T1:n [rpm] 428.57 428.59
T1:h_DT [mwc] 4.29 12.41
T1:h_Spiral [mwc] 304.18 349.80
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 5.56 % Q= 1.72 m3/s H= 341 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-914.11m
2 FRANCIS-TURBINE
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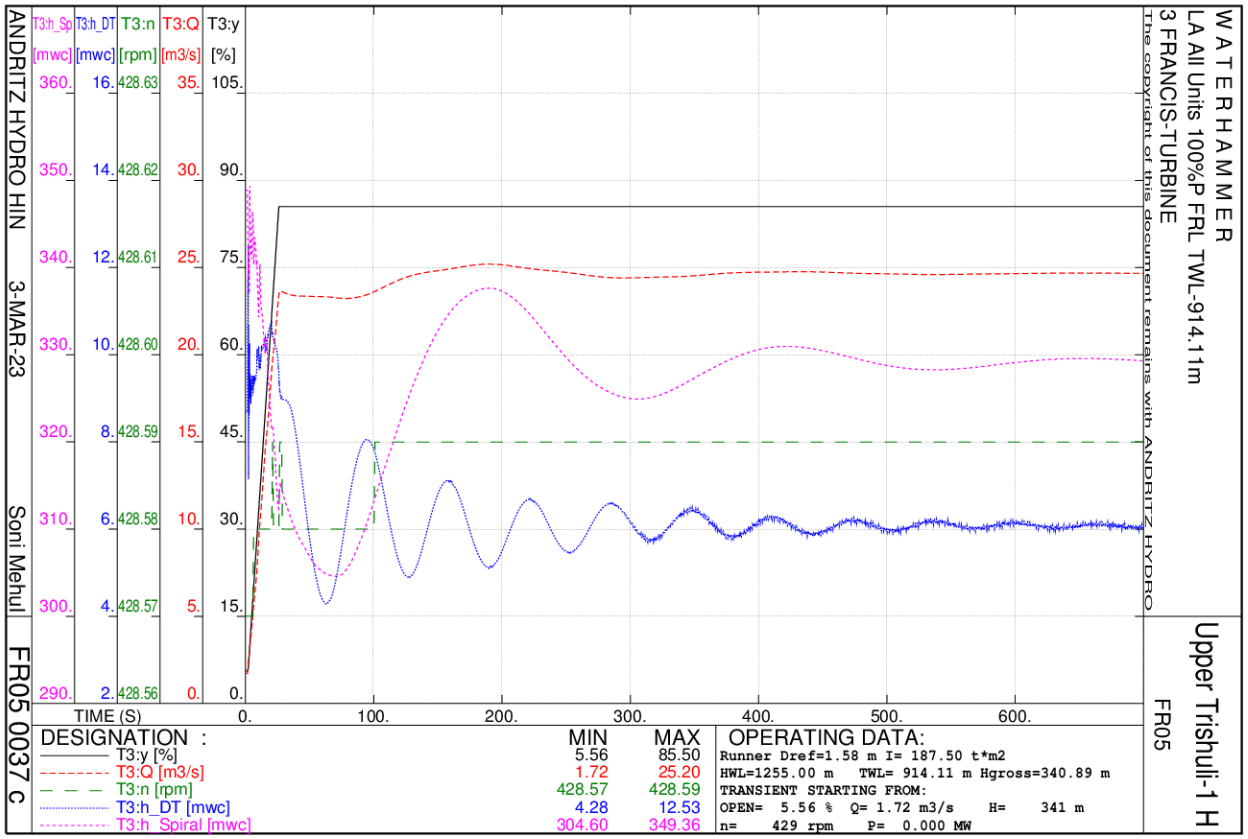
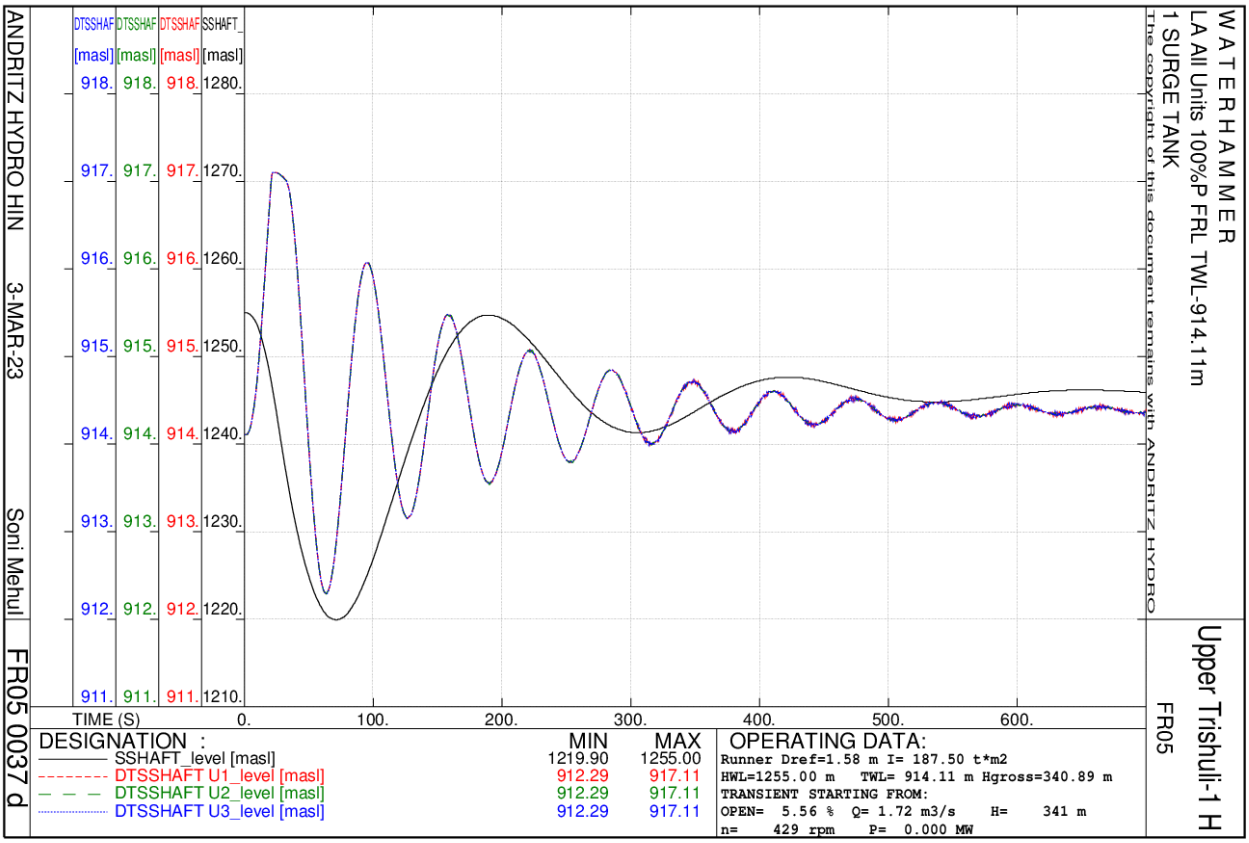
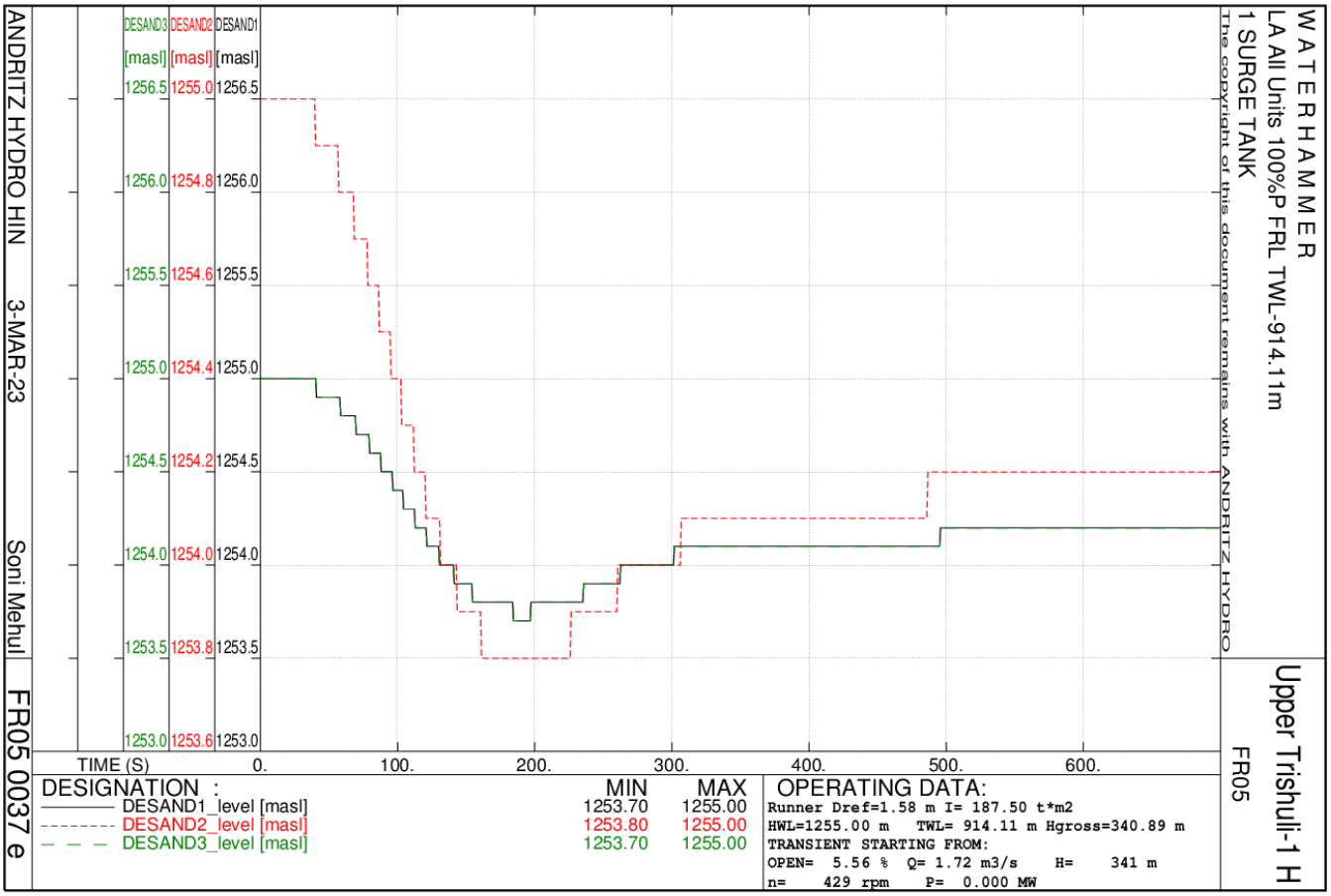
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0037 b
T2:h_Sp [mwc]
T2:h_DT [mwc]
T2:n [rpm]
T2:Q [m3/s]
T2:y [%]
TIME (S)
DESIGNATION :
T2:y [%] MIN 5.56 MAX 85.50
T2:Q [m3/s] 1.72 25.17
T2:n [rpm] 428.57 428.59
T2:h_DT [mwc] 4.28 12.47
T2:h_Spiral [mwc] 304.17 349.52
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 5.56 % Q= 1.72 m3/s H= 341 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-914.11m
3 FRANCIS-TURBINE
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0037 c
T3:h_Sp [mwc]
T3:h_DT [mwc]
T3:n [rpm]
T3:Q [m3/s]
T3:y [%]
TIME (S)
DESIGNATION :
T3:y [%] MIN 5.56 MAX 85.50
T3:Q [m3/s] MIN 1.72 MAX 25.20
T3:n [rpm] MIN 428.57 MAX 428.59
T3:h_DT [mwc] MIN 4.28 MAX 12.53
T3:h_Spiral [mwc] MIN 304.60 MAX 349.36
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 5.56 % Q= 1.72 m3/s H= 341 m
n= 429 rpm P= 0.000 MW


WATERHAMMER
LA All Units 100%P FRL TWL-914.11m
1 SURGE TANK
Upper Trishuli-1 H
FR05
ANDRITZ HYDRO HIN
3-MAR-23
Soni Mehul
FR05 0037 d
DTSSHAFT [masl]
DTSSHAFT [masl]
DTSSHAFT [masl]
SSHAFT [masl]
TIME (S)
DESIGNATION :
SSHAFT_level [masl] MIN 1219.90 MAX 1255.00
DTSSHAFT U1_level [masl] MIN 912.29 MAX 917.11
DTSSHAFT U2_level [masl] MIN 912.29 MAX 917.11
DTSSHAFT U3_level [masl] MIN 912.29 MAX 917.11
OPERATING DATA:
Runner Dref=1.58 m I= 187.50 t*m2
HWL=1255.00 m TWL= 914.11 m Hgross=340.89 m
TRANSIENT STARTING FROM:
OPEN= 5.56 % Q= 1.72 m3/s H= 341 m
n= 429 rpm P= 0.000 MW



FR05 0037 LA All Units 100%P FRL TWL-914.11m

ANNEXURE-1: Hydraulic Gradient Lines for Water Conductor System

Rev.0E

Hydraulic gradient lines for water conductor system are plotted for three cases – FR05 001, FR05 0034 and FR05 0036

In plots, Vertical Axis represents elevation while Horizontal Axis represents distance.

For the first Plot (a), ‘0' distance starts from Intake up to upstream surge shaft.

For the second Plot (b), '0' distance starts from vertical Pressure tunnel (Pipe P0012) after upstream surge shaft.

For the second Plot (c), '0' distance starts from Penstock tunnel (Pipe P0011) after vertical Pressure tunnel up to powerhouse.

For the third Plot (d), '0' distance starts from common Tail Race tunnel after common surge shaft up to TRT outlet.

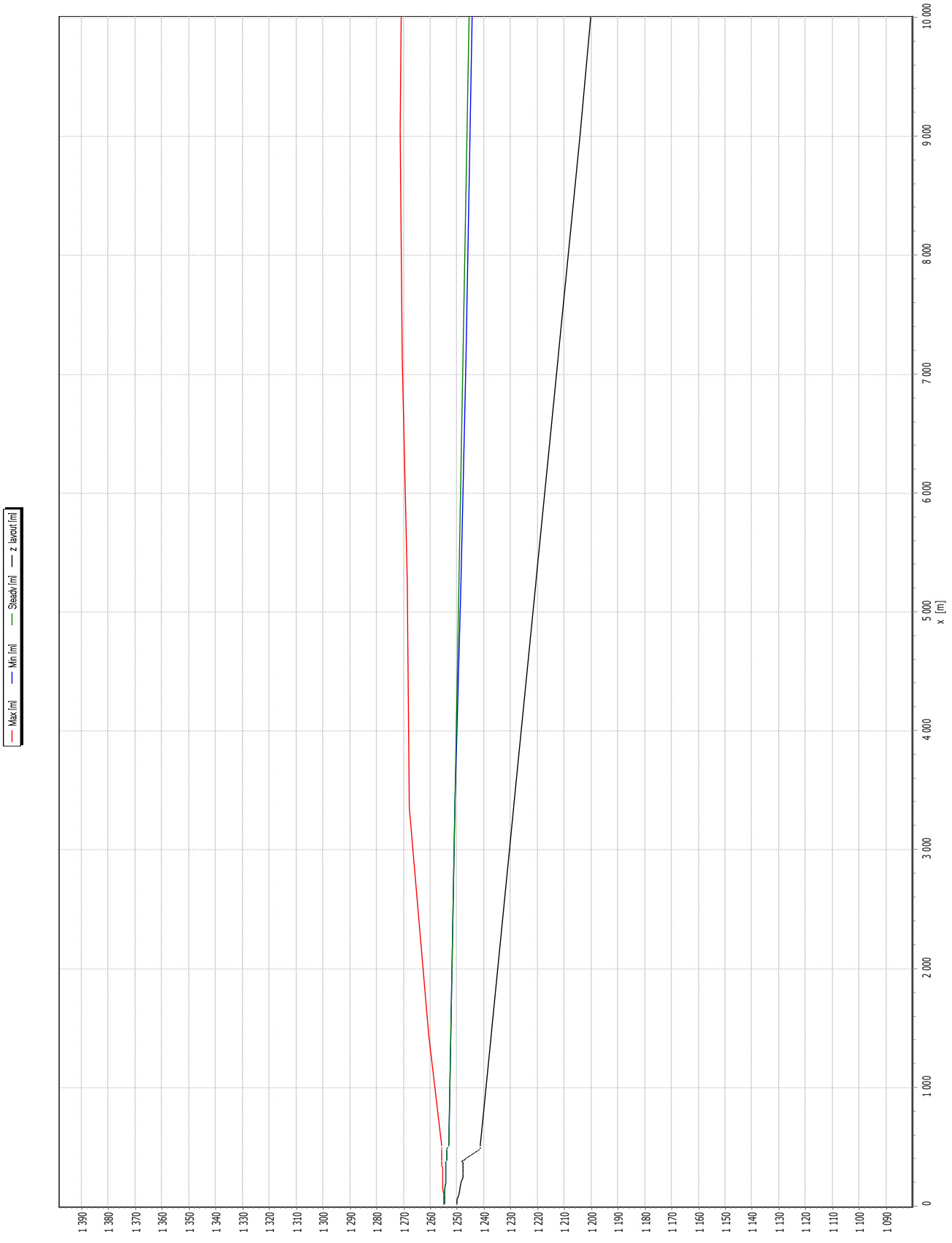
Accordingly, distance specified on abscissa (x-axis) on every plot could be read out and be collaborated to the Pipe Lengths given in 'Table 3.1: Data of waterway system'.

Following abbreviations are used on vertical axis on every plot:

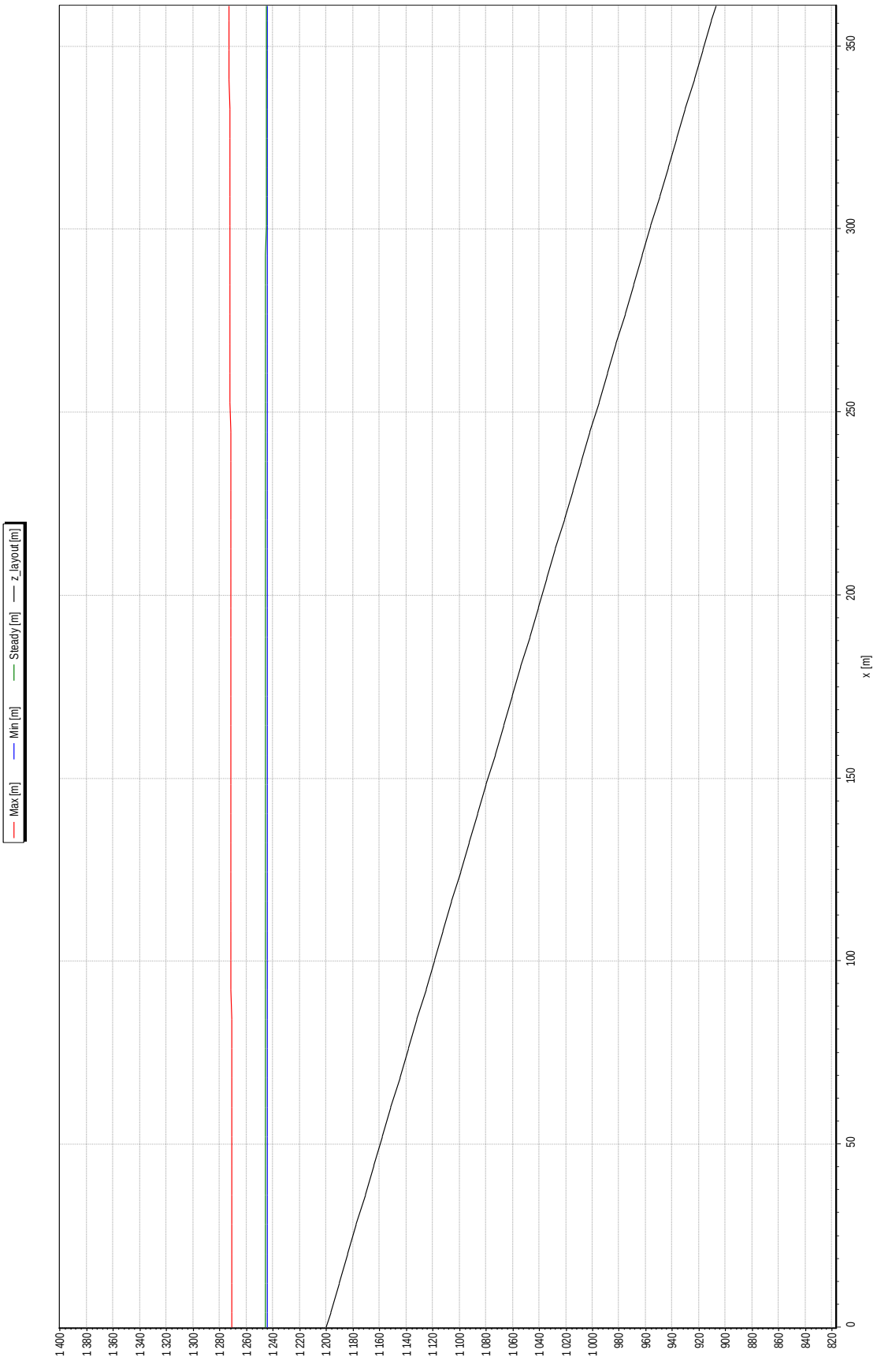
Max [m]	Maximum pressure line (Red colour line)
Min [m]	Minimum pressure line (Blue colour line)
Steady [m]	Initial condition pressure line (Green colour line)
Z_layout [m]	Elevation of pipe (Black colour line)

(1) Load Case: FR05 001: QSD-E 3U Hr 100%P

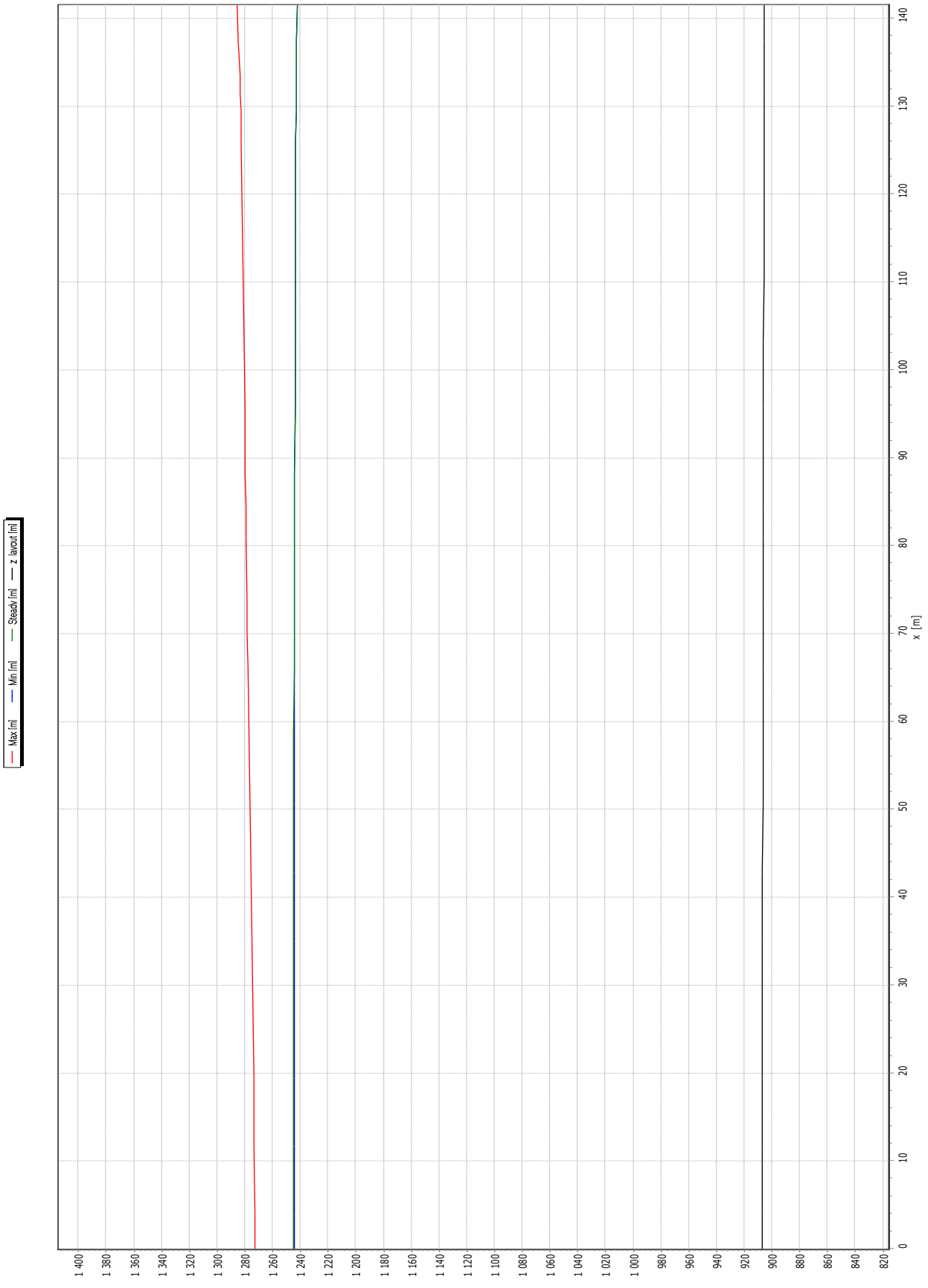
(a) Plot for Pipe 0001, Pipe 0002, Pipe 0005, Pipe 0008, Pipe 0009, Pipe 0010



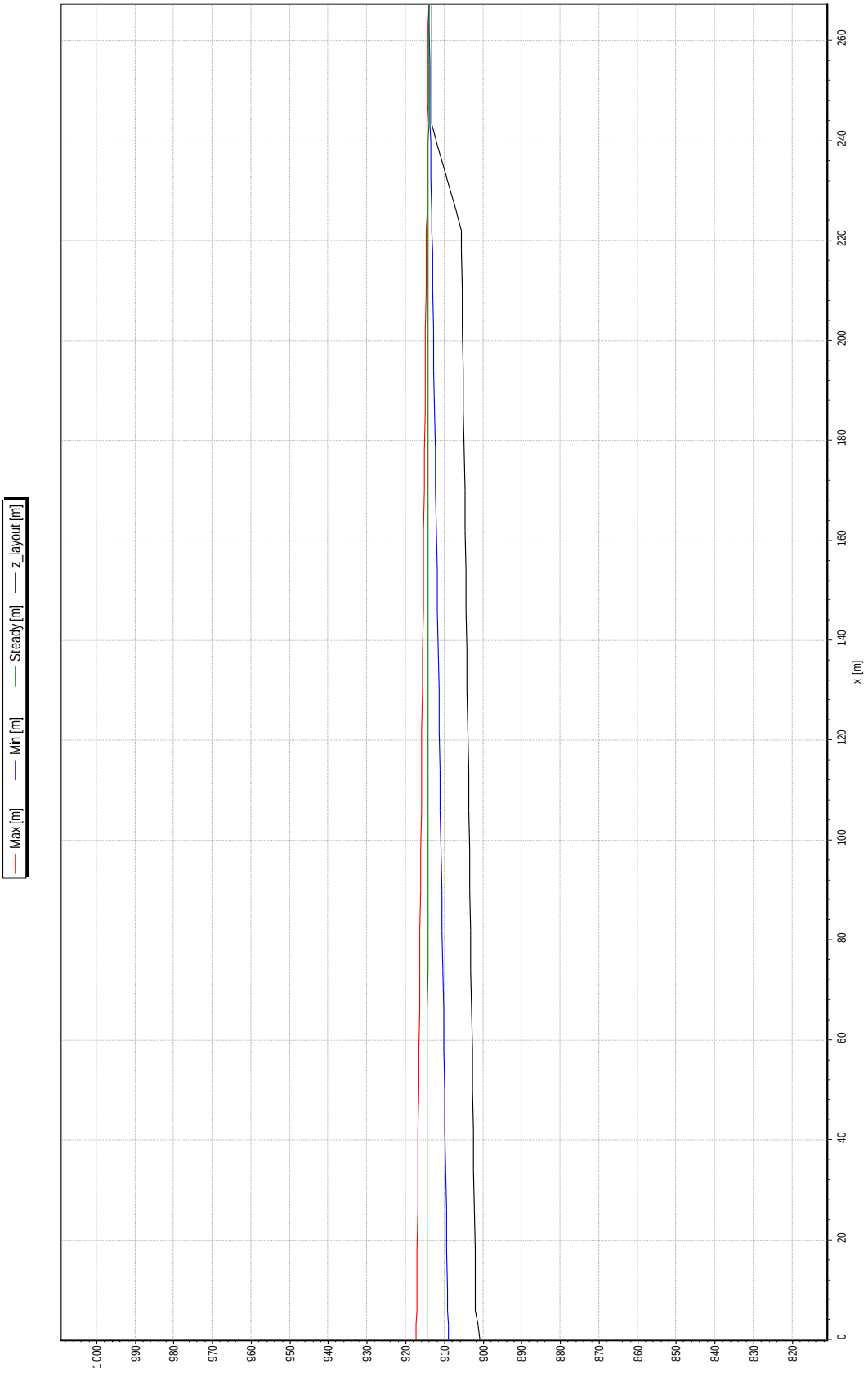
(b) Plot for Pipe 1011



(c) Plot for Pipe 1012, Pipe 1013, Pipe 1001, Pipe 1002, Pipe 1003

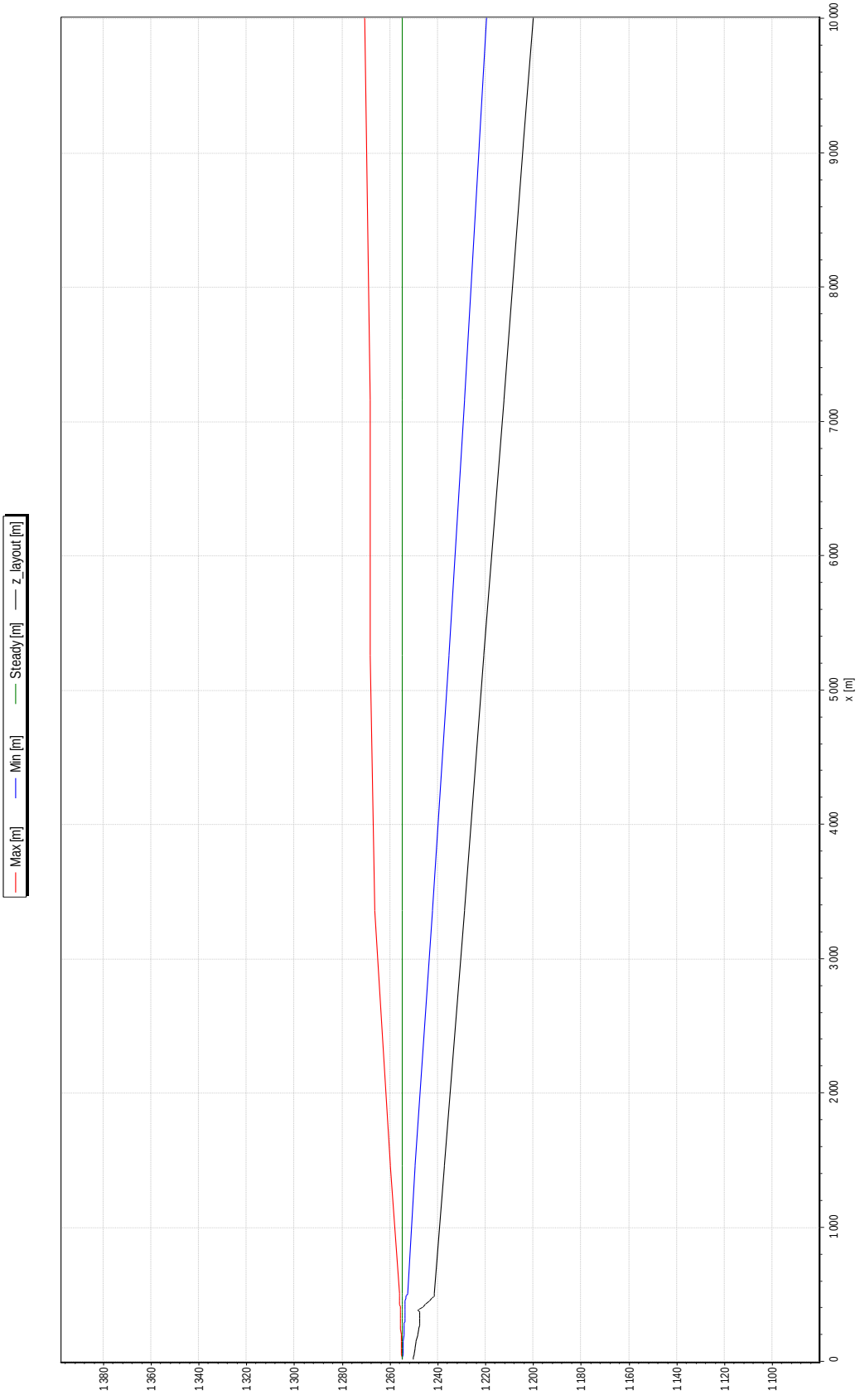


(d) Plot for Pipe 4001, Pipe 4002, Pipe 4003, Pipe 4004

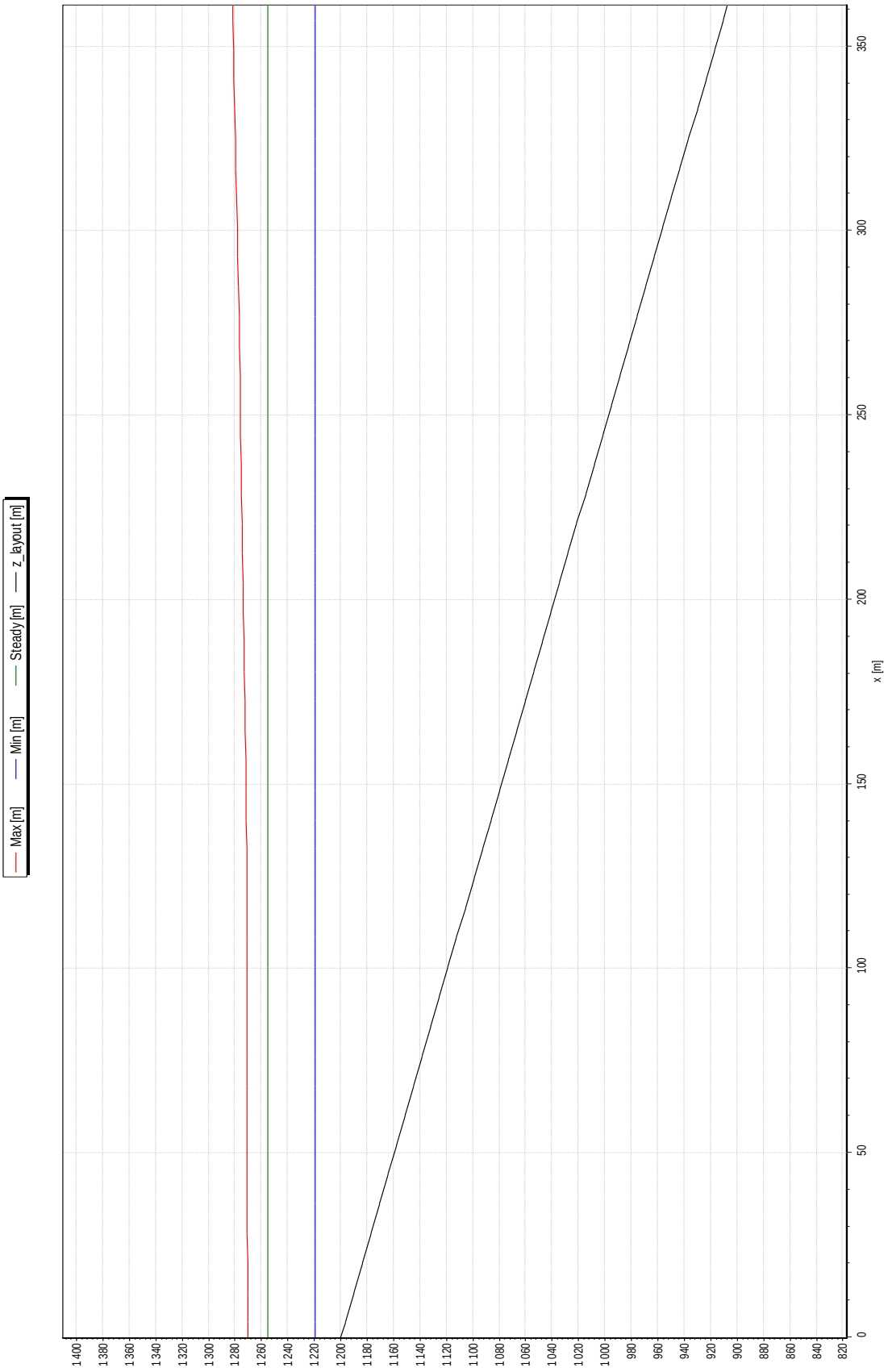


(2) Load Case: FR05 0034: LA+LR All Units 0-100-0%P FRL TWL-910m

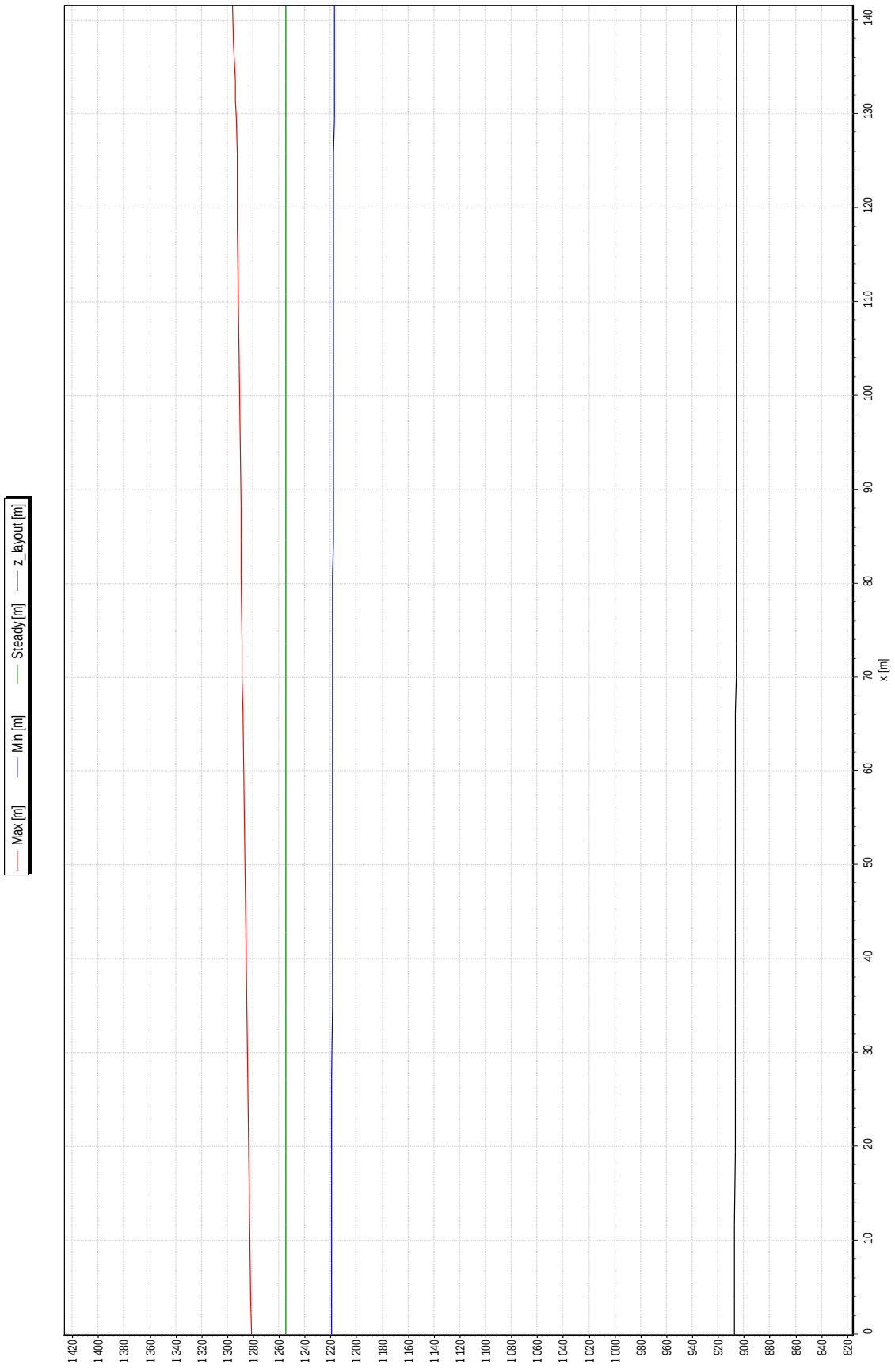
(a) Plot for Pipe 0001, Pipe 0002, Pipe 0005, Pipe 0008, Pipe 0009, Pipe 0010



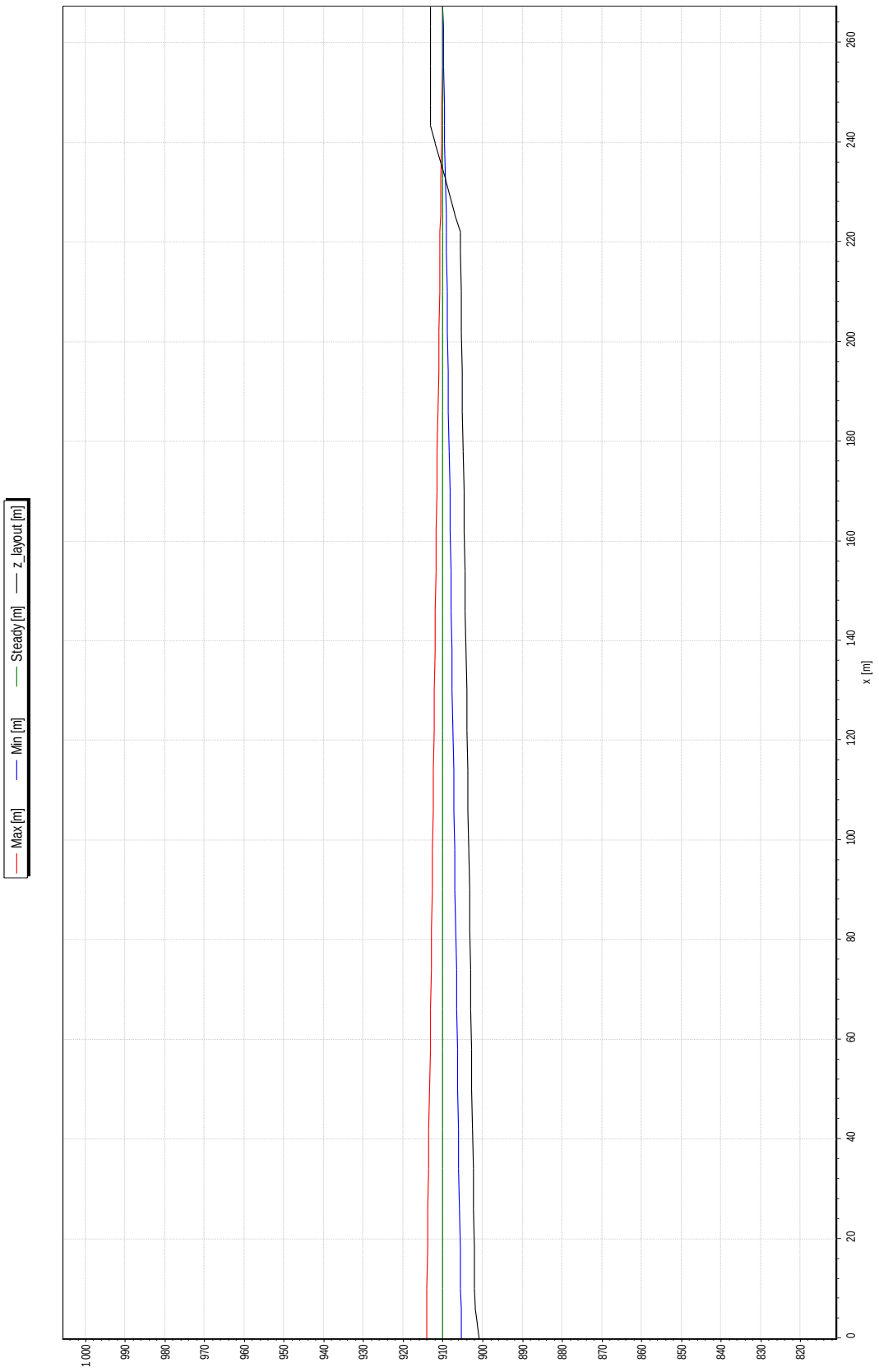
(b) Plot for Pipe 1011



(c) Plot for Pipe 1012, Pipe 1013, Pipe 1001, Pipe 1002, Pipe 1003

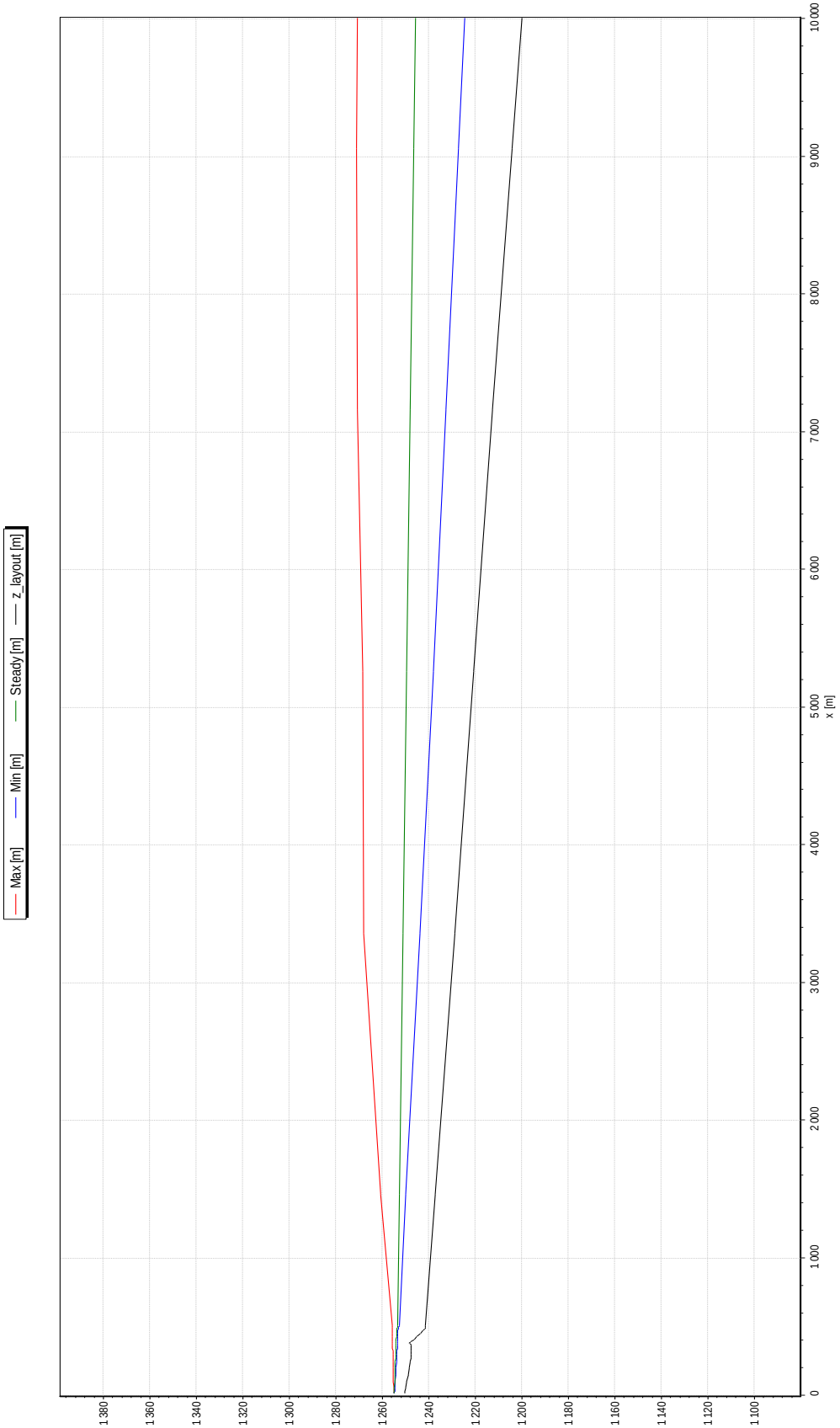


(d) Plot for Pipe 4001, Pipe 4002, Pipe 4003, Pipe 4004

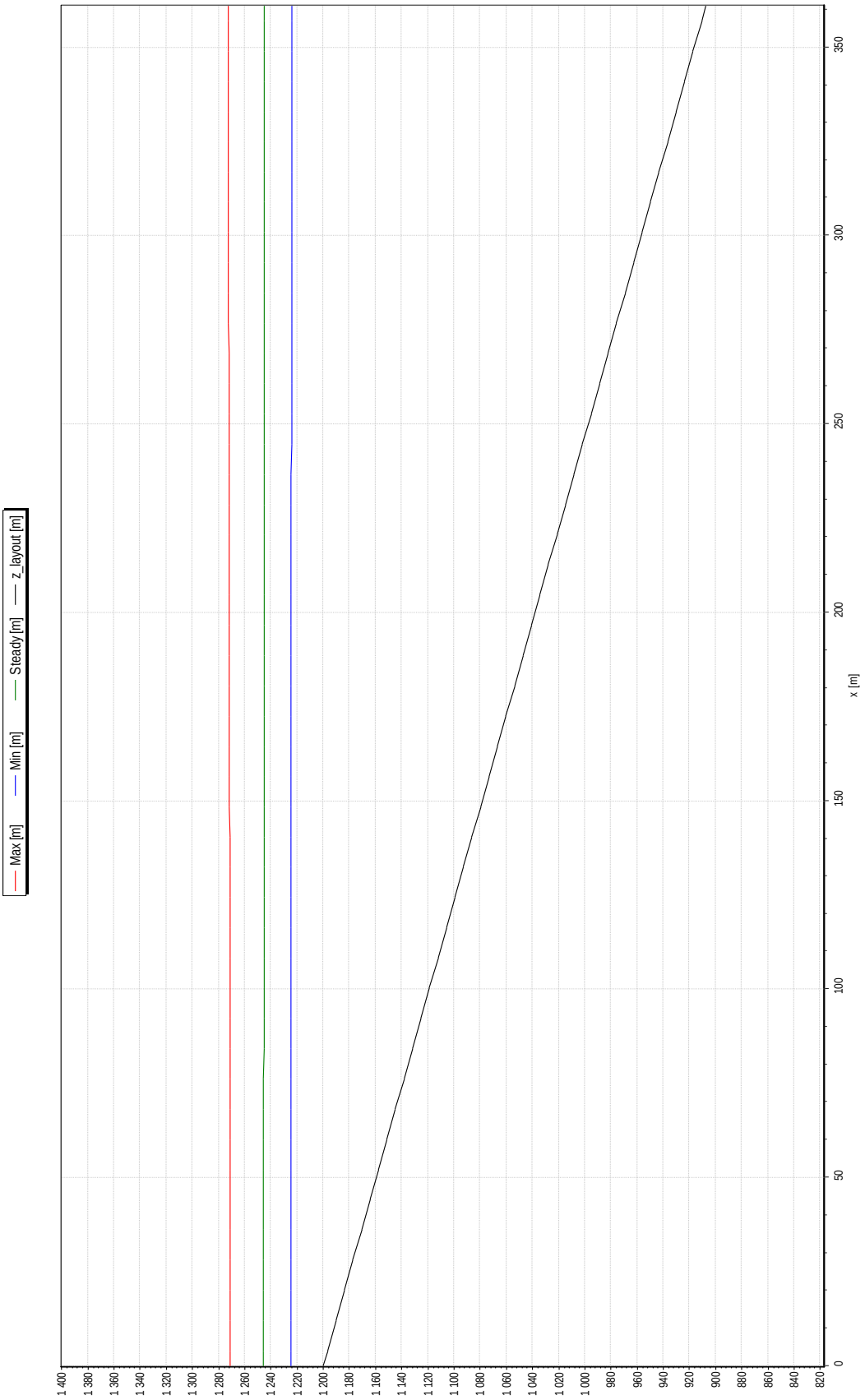


(3) Load Case: FR05 0036: QSD-E+SNL+LA All Units Hr 100%P

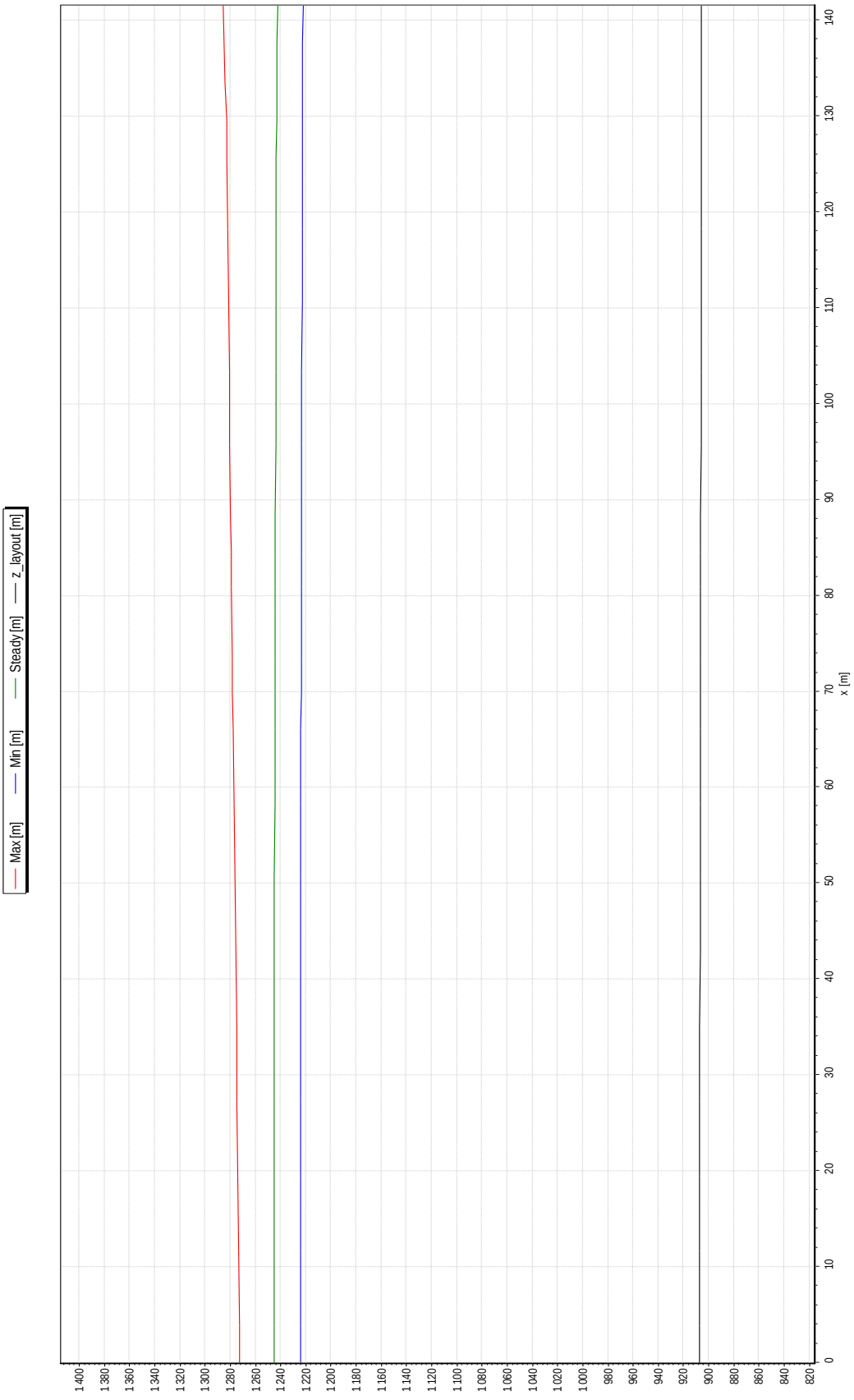
(a) Plot for Pipe 0001, Pipe 0002, Pipe 0005, Pipe 0008, Pipe 0009, Pipe 0010



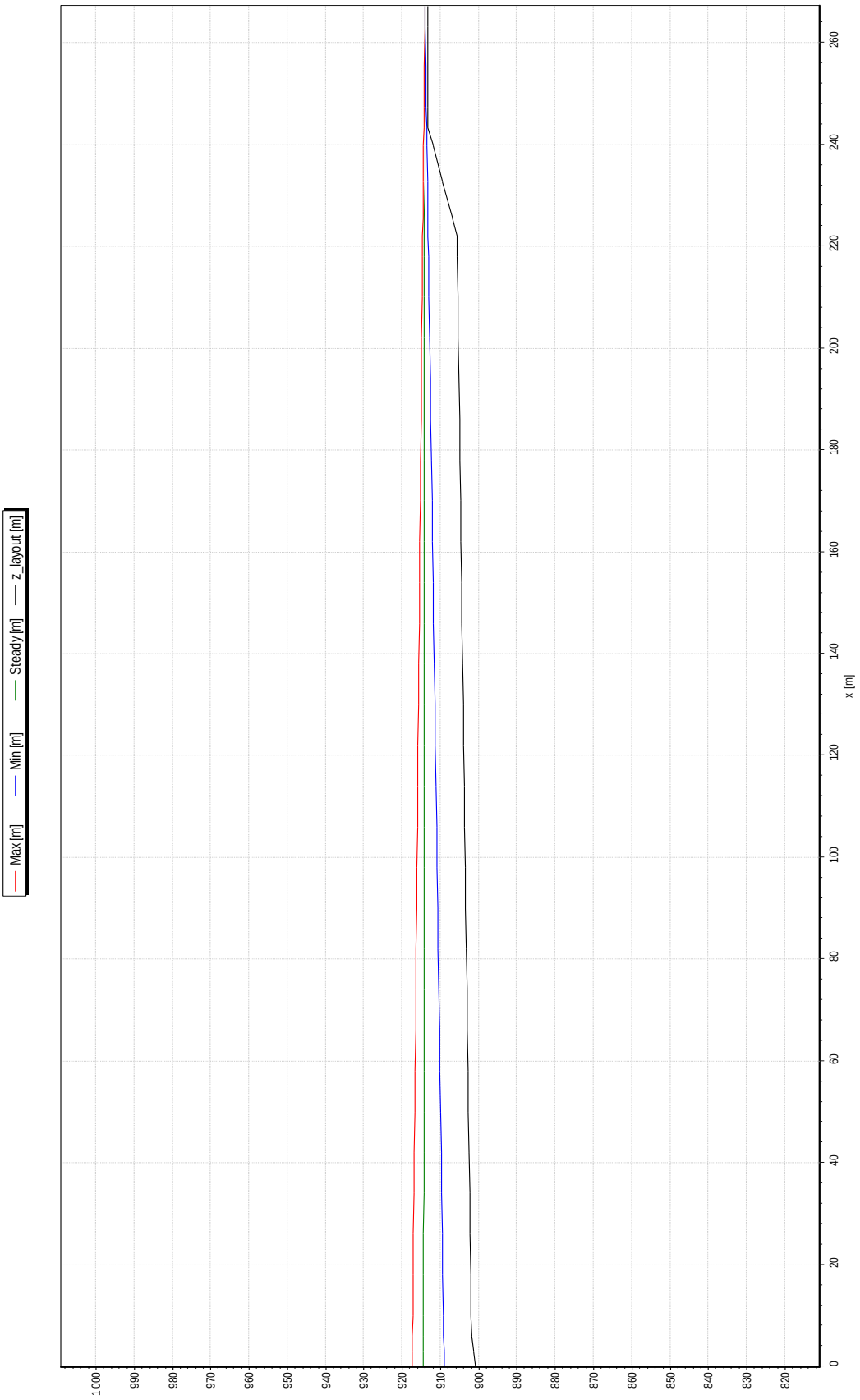
(b) Plot for Pipe 1011



(c) Plot for Pipe 1012, Pipe 1013, Pipe 1001, Pipe 1002, Pipe 1003



(d) Plot for Pipe 4001, Pipe 4002, Pipe 4003, Pipe 4004



ANNEXURE-2: Verification using the Thoma Stability Criterion for Mass Oscillations in Surge Tanks

Rev.02

Thoma criterion for stability and the dimension of the surge tank is expressed as below

$$A_{ST} \geq 1{,}5\frac{A_T L_T}{2g\alpha H_{eff}}$$

A_{ST} - Cross sectional area of surge tank, m^2
A_T – Equivalent Cross-sectional area of tunnel, m^2
L_T - Length of tunnel, m
g - Acceleration of gravity, (9.78 m/s^2)
α - Coefficient of hydraulic losses such that $h_f = \alpha V^2$ Rev.04
H_{eff} - Effective (Net) head on turbines, (327 mWc)
1.5 – Safety factor, over calculated value Rev.0E

To be on safer side 1.6 Safety factor considered for calculation, instead of 1.5 in above formula.
Head race tunnel has different cross section areas across length. Also considering connecting tunnel to calculate Surge Tank size.

Position	Section	Area	Length	Discharge	Flow rate	Roughness	Friction head loss*
	D (m)	A_T (m^2)	L (m)	Q (m^3/s)	V=Q/A(m/s)	n	h_f (m)
headrace tunnel(shotcrete)	7.21	43.09	5598	76	1.76	0.025	5.678 (5.071+0.607)
headrace tunnel(concrete)	6.5	33.18	3906	76	2.29	0.016	3.483
Connecting tunnel (concrete)	2.0	3.14	4	66	21.02	0.016	0.4787 (0.452+0.0267)

* Friction Head Loss values are taken from Head Loss Calculation provided by Power China on 26 JULY 2021

As tunnel cross-section comprises various lengths of various areas, AT may be taken as equivalent area of head race tunnels and connecting tunnels.

$$Equivalent\ Cross\ Sectional\ Area, A_T = \frac{\sum L}{\sum \frac{L}{A_T}}$$

$$A_T = \frac{9508}{248.9}$$

$$A_T = 38.2\ m^2$$

Surge Tank Cross-Sectional Area

$$A_{ST} = 1.6\ x\ \frac{38.2\ x\ 9508}{2x9.78x\left[\frac{5.678}{1.76^2} + \frac{3.483}{2.29^2} + \frac{0.4787}{21.02^2}\right] x327}$$

$$A_{ST} = 38.55\ m^2$$

$$\text{Surge Shaft Diameter} = 7.01\ m$$

In present calculation, Surge Shaft diameter taken is 8.5m which is higher than the calculated here using Thoma Criterion.

ANNEXURE-3: Justification of Requirement of Draft Tube Shaft as Surge Tank

Rev.02

To justify requirement of surge tank at individual TRT downstream of Turbine, transient calculation has been carried out without considering Draft Tube shaft as surge tank.

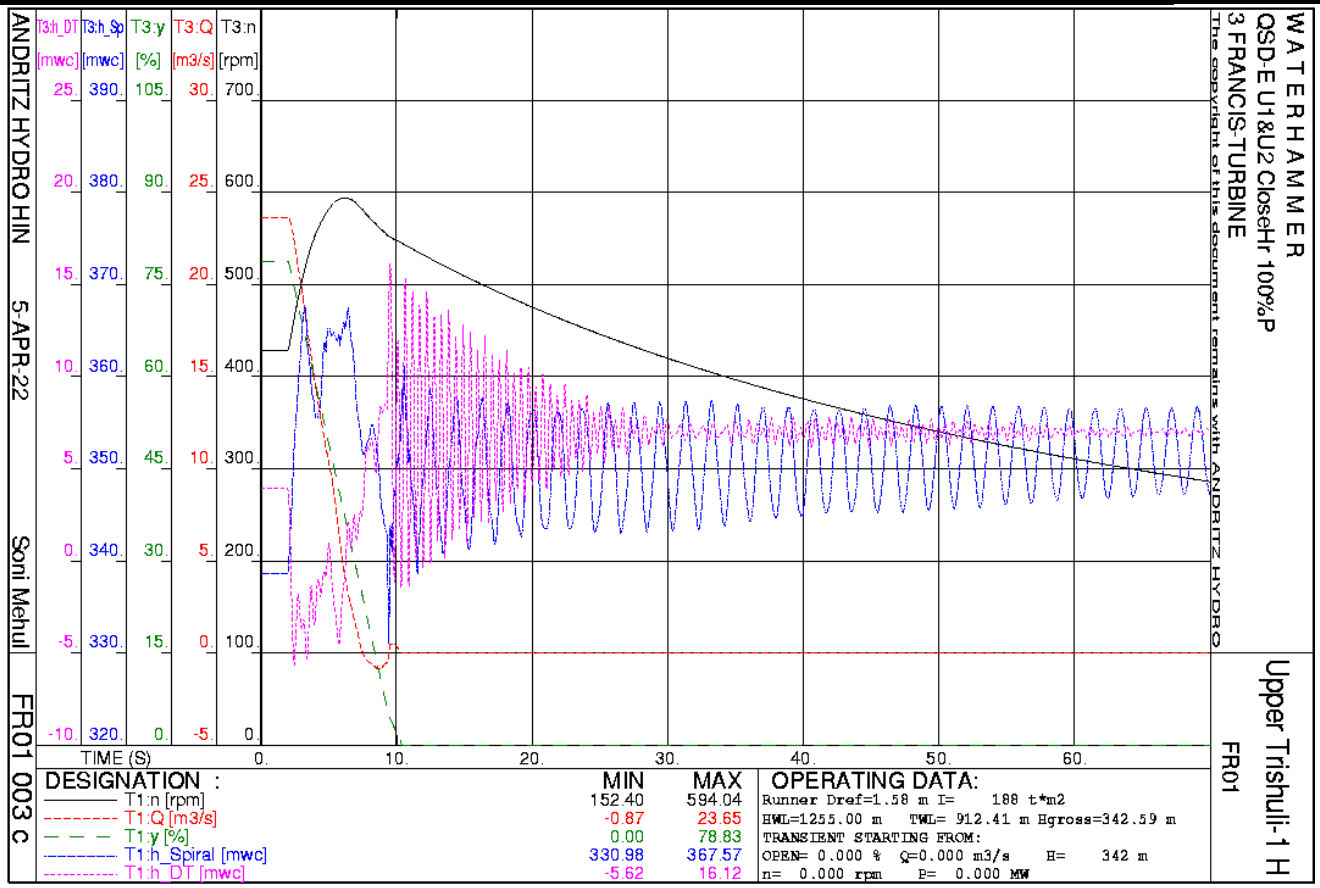
Few critical cases have been calculated and tabulated in below table.

Case #	Description	Pressure at Runner bottom/in Draft tube, [m]
	Cases Without DT Shaft	
FR01 001	Load Rejection 3 Units 74.5MW H-327m	-4.49
FR01 003	Load Rejection Units 1&2 closed Unit 3 running 74.5MW H-327m	-5.62
	Cases With DT Shaft	
FR03 001	Load Rejection 3 Units 74.5MW H-327m	-1.01
FR03 003	Load Rejection Units 1&2 closed Unit 3 running 74.5MW H-327m	-1.36

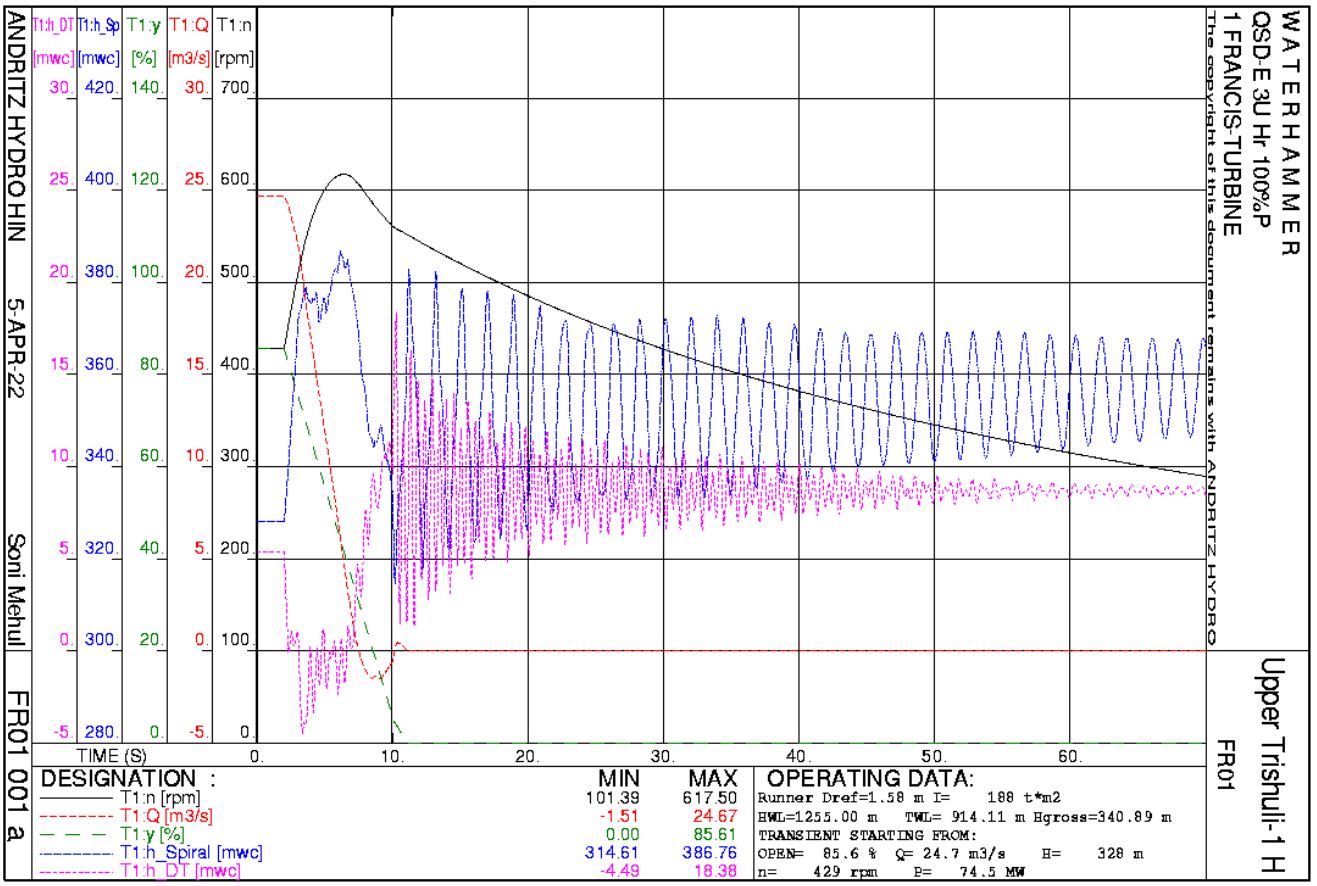
Without Draft Tube shaft at individual TRT downstream of turbine, high negative pressure under runner is observed during load rejection cases.

With Draft Tube shaft at individual TRT downstream of turbine, the negative pressure at runner bottom can be maintained within acceptable limit.

Hence, it is recommended to provide DT shaft at transformer cavern or equivalent volume surge tank.



FR03 001: Load Rejection (QSD-E) _ 3 Units 74.5MW H-327m



FR03 003: Load Rejection (QSD-E) _ Units 1&2 closed & Unit 3 running 74.5MW H-327m

ANNEXURE-4: Impact of Connection Pipe (Orifice) Size on U.S.W.L and Pressure in HRT

Rev.04

Transient calculations have been performed to check the effect of various sizes of connection pipe (orifice) between HRT and surge shaft.
The calculations have been carried out to check effect of connection pipe sizes on…

- U.S.W.L. (Upsurge Water Level in surge shaft) and
- Pressure in HRT at the connection point between HRT and connection pipe. The elevation at this connection point is 1200.064masl.

The sample calculation has been simulated with connection pipe diameter of 2m, 3m and 4.36m.
Calculations have been performed for the load case "QSD-E 3U Hr 100%P".

- Connection pipe size: 2.0m

Case #	Description	Upstream Surge Shaft Levels, masl		Pressure at connection point, masl
		Maximum	Minimum	
FR04 001	QSD-E 3U Hr 100%P	1264.3	1241.2	1271.5

- Connection pipe size: 3.0m

Case #	Description	Upstream Surge Shaft Levels, masl		Pressure at connection point, masl
		Maximum	Minimum	
FR04 0051	QSD-E 3U Hr 100%P	1267.3	1232.5	1267.4

- Connection pipe size: 4.36m

Case #	Description	Upstream Surge Shaft Levels, masl		Pressure at connection point, masl
		Maximum	Minimum	
FR04 0050	QSD-E 3U Hr 100%P	1268.1	1229.4	1268

CONCLUSION:

(1) U.S.W.L.

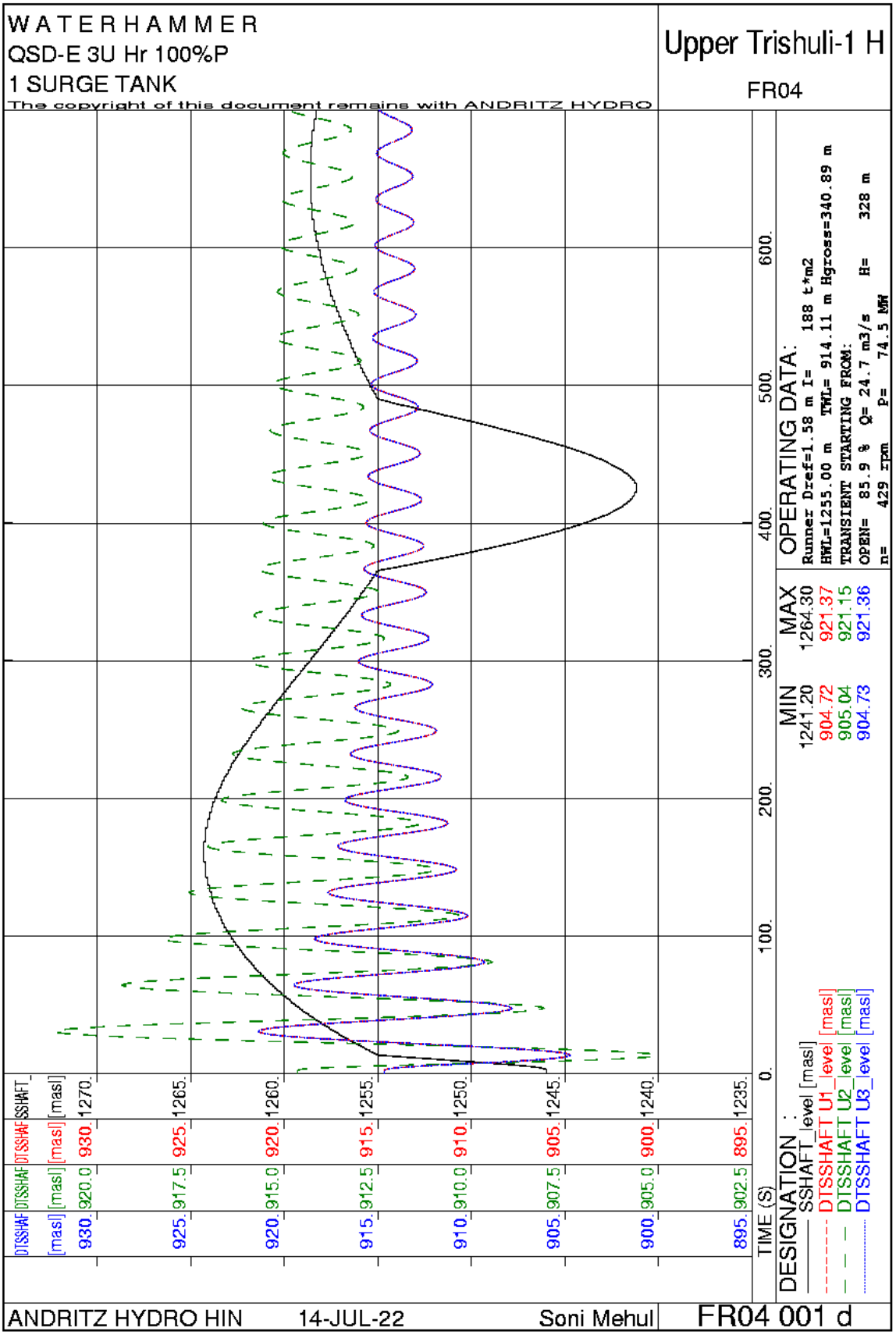
For all the cases, U.S.W.L. breaches allowable level 1260.696masl specified in the contract.
For load rejection case with 2.0m connection pipe, U.S.W.L. is the least one, lower by 3.0m and 3.8m respectively for connection pipe diameter 3.0m and 4.36m.

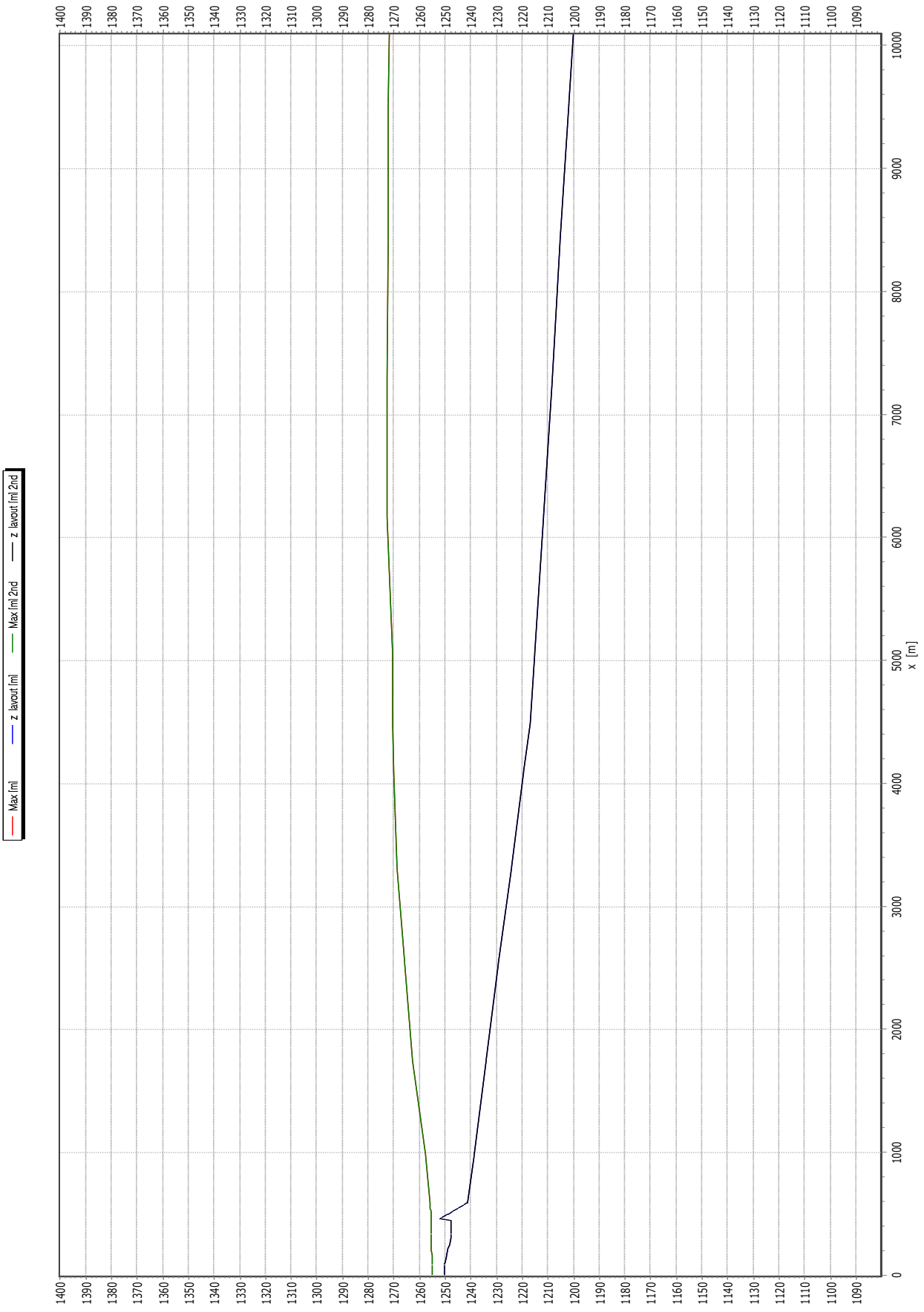
(2) Pressure in HRT at the connection point between HRT and connection pipe

For all the cases, maximum pressure at the connection point between HRT and connection pipe has small difference.
Load rejection case with 2.0m connection pipe is having the highest pressure, higher by 4.1m and 3.5m respectively for connection pipe diameter 3.0m and 4.36m.

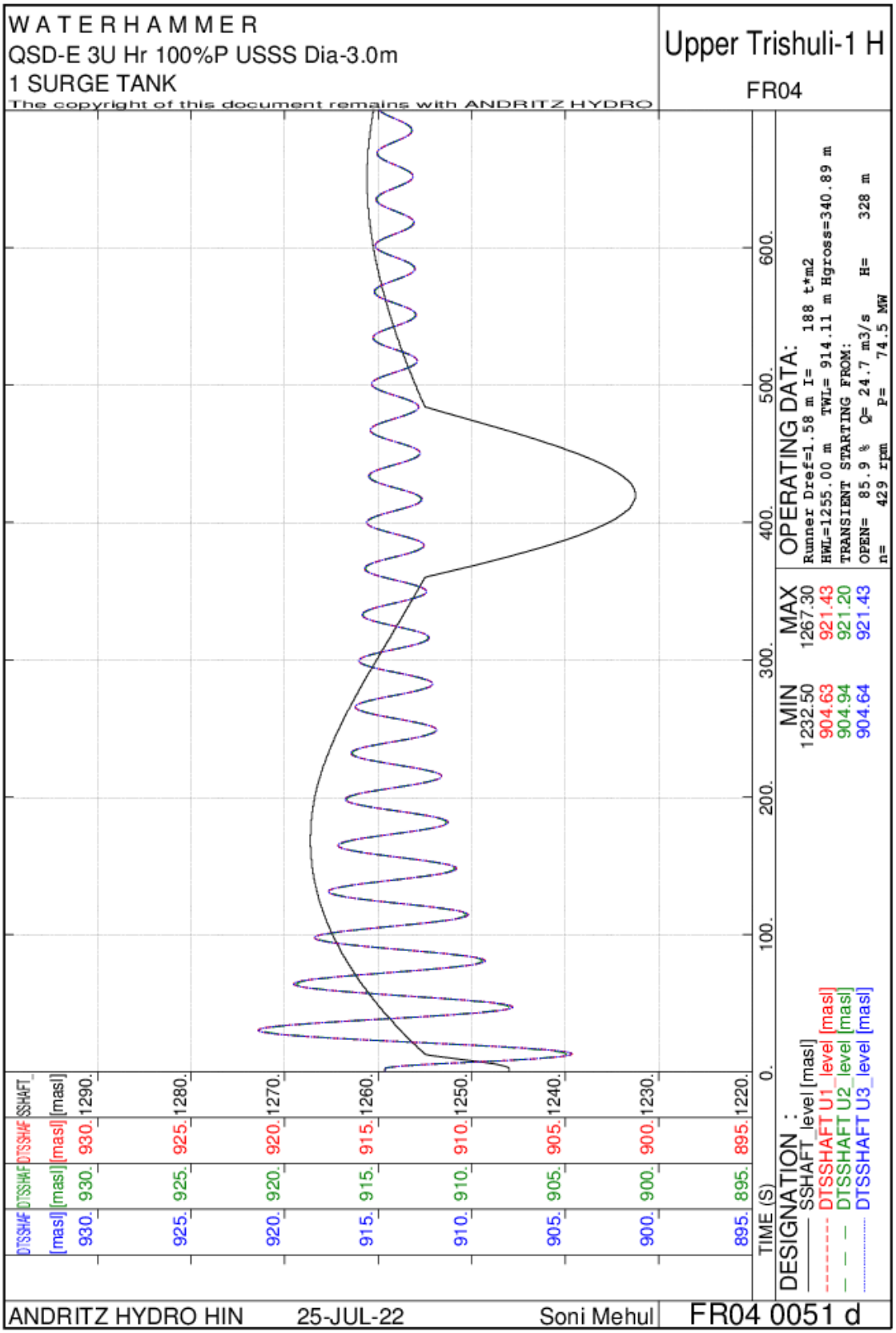
Plots for all three scenarios are enclosed hereafter.

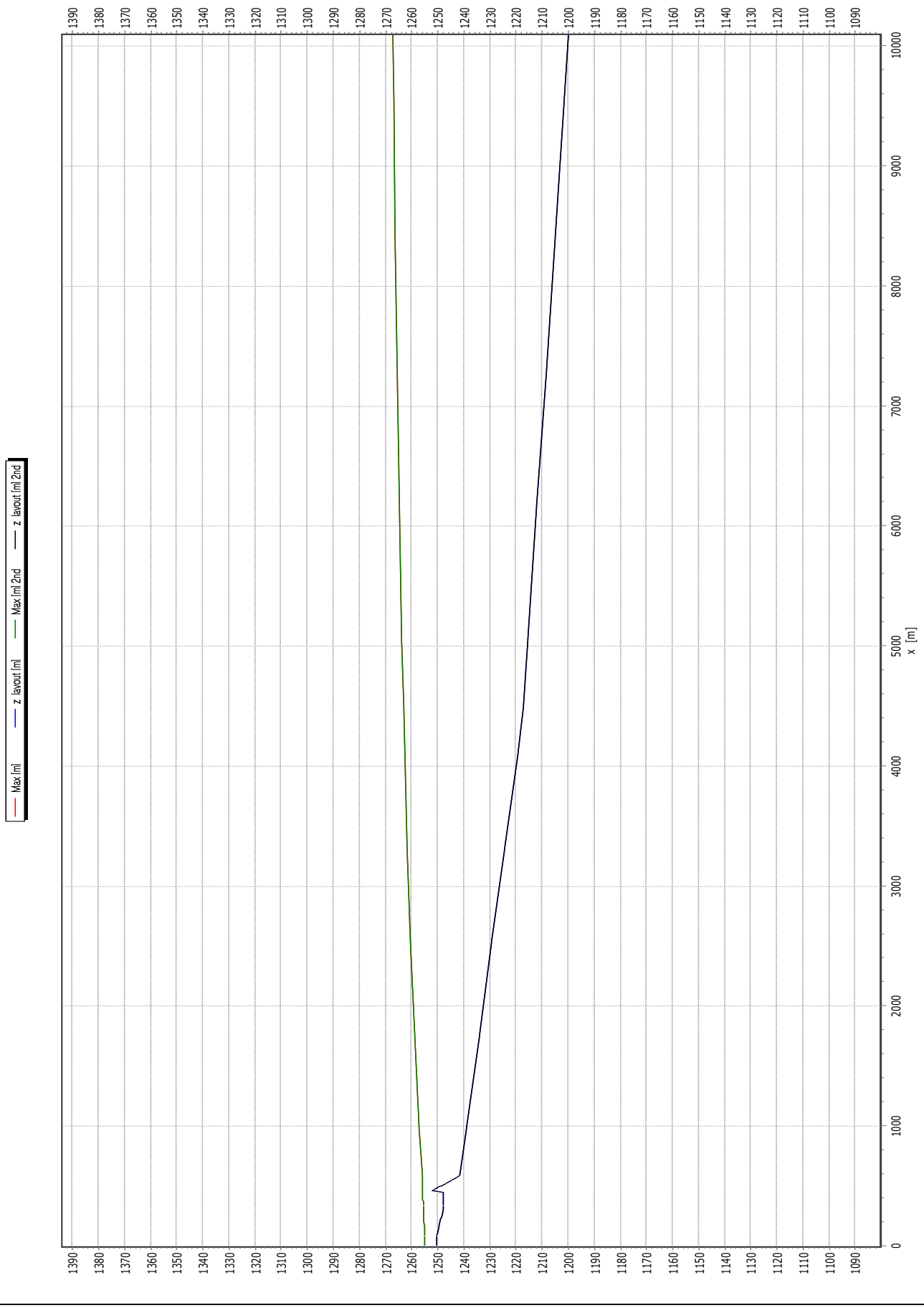
- Orifice size: 2m



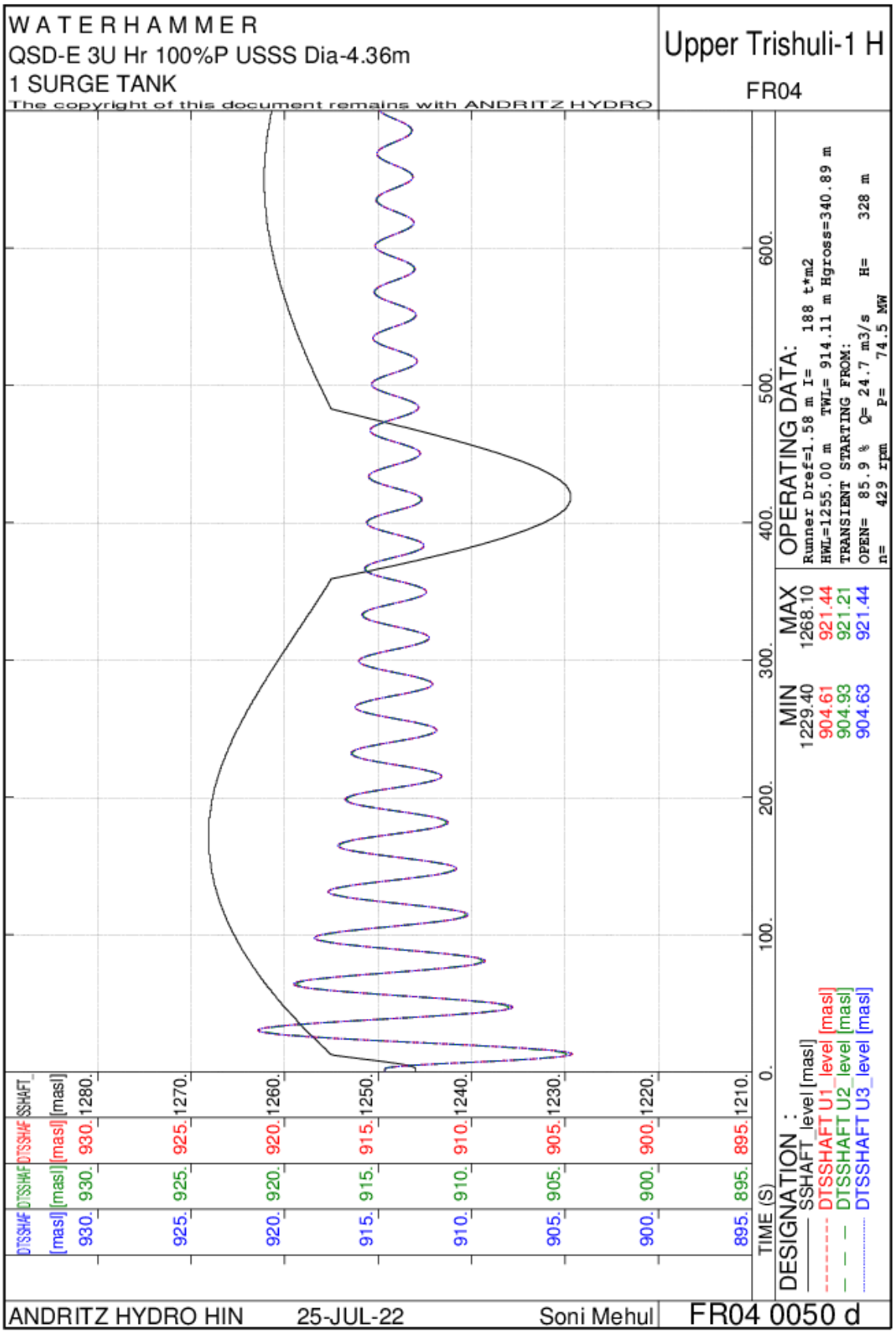

Max [m]
z_lavout [m]
Max [m] 2nd
z_lavout [m] 2nd
x [m]

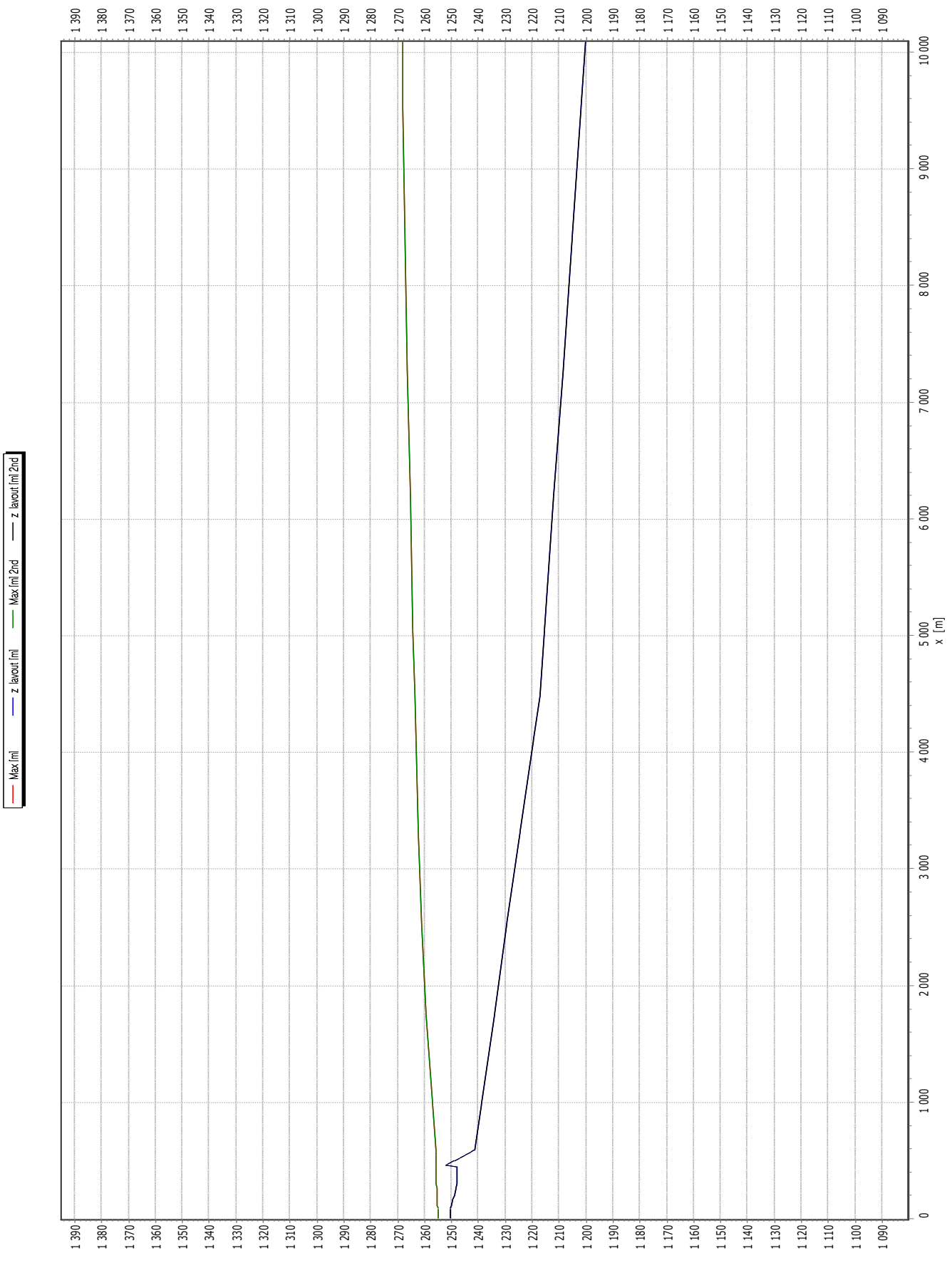
- Orifice size: 3m




Max.hml
z layout.hml
Max.hml 2nd
z layout.hml 2nd
x [m]
1390
1380
1370
1360
1350
1340
1330
1320
1310
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

- Orifice size: 4.36m




Max (m)
z layout (m)
Max (m) 2nd
z layout (m) 2nd
1 390
1 380
1 370
1 360
1 350
1 340
1 330
1 320
1 310
1 300
1 290
1 280
1 270
1 260
1 250
1 240
1 230
1 220
1 210
1 200
1 190
1 180
1 170
1 160
1 150
1 140
1 130
1 120
1 110
1 100
1 090
0
1 000
2 000
3 000
4 000
5 000
6 000
7 000
8 000
9 000
10 000
x [m]